AN INVESTIGATION ON STRENGTH OF CONCRETE WITH BANANA STEM FIBRES SYNTHESIZED AS MICRONS

A PROJECT REPORT

submitted by

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in partial fulfilment for the award of the degree

of

BACHELOR OF ENGINEERING

in

CIVIL ENGINEERING

PSG INSTITUTE OF TECHNOLOGY AND APPLIED RESEARCH

ANNA UNIVERSITY : CHENNAI 600 025

APRIL 2018

BONAFIDE CERTIFCATE

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ACKNOWLEGEMENT

We express our whole hearted indebtedness to our management for their warm blessings, moral support and constant encouragement at various stages of the course and for providing all necessary facilities for completing this project.

We sincerely express our thanks to the esteemed Principal of our Institution **Dr.P.V.MOHANRAM** for his support and encouragement on this project. Also we extend our heartfelt thanks to our Vice Principal **Dr.G.CHANDRAMOHAN** for his continuous support in all aspects.

We express our esteemed gratefulness to our Project Guide **Dr.M.I.ABDUL ALEEM,** Head of the Department, Department of Civil Engineering **for** providing his constant suggestions, encouragements and valuable guidance rendered to us in the preparation and completion of this project work.

We also thank our Project Coordinators **Mr.S.Elayaraja**, Assistant Professor (Sr.Gr.) and **Mr.S.R.Mahesh**, Assistant Professor (Sl.Gr.) for their support and suggestions.

We committed to place our thanks to all our Faculty members, Non Teaching Staffs, Family and Friends who played a supportive role throughout the Project.

TABLE OF CONTENTS

ABSTRACT

Construction materials are more sustainable if it is from a renewable resource. Plant based natural fibres are low cost renewable materials which can be available in plenty in many countries. Recent studies have indicated that banana stem fibre possesses a lot of advantageous physical and chemical properties which leads its application in the construction industry. Banana stem fibres are environment friendly and have some important attributes such as low density, light weight, low cost, high tensile strength as well as being water and fire resistant. Banana stem fibre which is extracted from its stem in the Coimbatore region had undergone a chemical treatment to increase its strength and to avoid decay and incorporated into concrete. Banana stem fibres of Nendran breed is chosen in this study because of its high strength and plently available in the region. The paper presents a summary of research progress on banana stem fibres synthesized as microns to increase the strength of concrete.

LIST OF TABLES

LIST OF FIGURES

LIST OF SYMBOLS

f_{ck}	-	Characteristic Compressive Strength of Concrete
f'_{ck}	-	Target Average Compressive Strength of Concrete
f_{cr}	-	Design Average Strength of Concrete
s	-	Standard Deviation
BSF	-	Banana Stem Fibres
FTIR	-	Fourier Transform Infra Red
SEM	-	Scanning Electron Microscope

CHAPTER 1

INTRODUCTION

1.1. GENERAL

Construction is one of the fast growing fields worldwide. Concrete is the second most consumed material after water, with nearly three tonnes are used annually by each person in the planet. The demand for low cost sustainable building materials is growing as social, economic and environmental issues evolve in today's society. During last three decades the global need for affordable housing has stimulated extensive research on enhancing the strength of concrete. Natural building materials offer a number of environmental benefits, they are typically produced using simple, quick processes without the need for highly skilled labour, with low embodied energy and by using raw materials from plant waste and construction materials. Different groups in tropical regions have conducted an important study of concrete reinforced with plant fibres. Indeed plant fibres offer a cheap and sustainable approach that can be used to reduce the overall cost of construction materials and electricity consumption. The goal for developing such alternative technologies is to promote sustainable building materials. The fibre reinforcement is to improve the mechanical properties of concrete. A major advantage concerning fibre reinforcement of a brittle material (e.g. Cement Paste, Mortar or Concrete) is the composite behavior which can crack.

1.2. BACKGROUND

Cement concrete composite is the most important building material and its consumption is increasing in all countries. The only disadvantage of cement concrete is its brittleness, with relatively low tensile strength and poor resistance to crack opening ,propagation and negligible elongation at break. Inorder to overcome these discrepancies reinforcement with dispersed fibres might play an important role. Steel is the conventional reinforcing material in concrete. Although steel enhances the strength and modulus of concrete but it lacks the ability to absorb mechanical impact. The steel makes the reinforced cement concrete (RCC) structure heavy and in due course of time as a result of water/moisture diffusion through micro crack developed in the RCC structure steel starts corroding leading to failure of the concrete. On the contrary, if the micro crack formation and propagation can be minimized by dispersion of short fibres, the mechanical properties as well as the durability of the concrete can be improved. Such a system would be able to bear high level static as well as dynamic stress.

Natural (cellulosic) fibres might offer the opportunity as a convenient reinforcing agent in concrete composite due to its low density. In recent years, considerable research efforts are found to develop high-strength, natural fibres reinforced concrete composites, mostly for using as building and construction materials.

Natural fibres, isolated from plants, are classified into three categories, depending on the part of the plant they are extracted from. The first category is the so called fruit fibre (e.g., coir, cotton, etc.) which are extracted from fruits of the plant. The second category of the fibre is found in the stems of the plant (e.g., banana, flax, ramie, hemp, etc). Such fibres are known as bast fibre. The third category is the fibres extracted from the leaves (e.g., sisal, date palm, oil palm, etc.).

Chemically modified banana fibres have been decided to be used as reinforcing element in cement concrete in which treatment will chemically bridge banana in one side and cement on the other side. Chemically modified banana fibre is expected to act as a flexible reinforcing agent in cement concrete enabling it to transmit both static and dynamic stresses to its surrounding bulk as well as absorb a portion of the stress by virtue of its flexible nature. An optimized weight fraction of chemically modified banana fibre in cement concrete may lead to excellent mechanical properties. It has been anticipated that modification of banana fibre with polymer will reduce degradation possibilities.

Fibre reinforced concrete has been investigated extensively to make light weight corrosion free structural materials. There are global attempts to use natural fibres as reinforcing agent in cement concrete matrices. The advantages of natural fibres over the conventional reinforcing fibres like glass, synthetic (e.g., polypropylene, polyethylene and polyolefin, polyvinyl alcohol), carbon, steel etc., are abundant availability, low cost, less abrasiveness, ability to absorb mechanical impact, easy to handle and process and environmental friendliness. These composites can be used in various fields of applications such as permanent frameworks, paver blocks, wall panels, pipes, long span roofing elements, strengthening of existing structures and structural building members.

The natural fibre reinforced concrete composites present enhanced strength and are likely to encounter a range of static overload and cyclic loading due to possible wind or earthquake loading. When concrete matrix cracks under load, the fibres bridge the cracks and transfer the loads to its surrounding bulk as well as absorb a portion of the load by virtue of its flexible nature. Several investigations have been carried out with different lignocellulosic fibres like, wheat straw, rice straw, coir, hazelnut shell, bagasse, oil palm residues, arhar stalks, etc., to find the potentiality of natural fibres as an effective reinforcement in concrete composites. But no report is found on the use of banana fibre as micron sized reinforcement in cement concrete.

Based on the present scenario it has been anticipated that the banana fibre reinforced cement concrete may find potential application as structural items in construction industry. Being a potential agricultural product, the use of banana as reinforcing fibre in cement concrete will promote banana farming industries as well as produce better advanced composites.

1.3. BANANA STEM FIBRES

Banana is cultivated in over 120 countries throughout the tropical and subtropical regions of the world. India is one of the top ten largest banana producing countries in the world. About 17% of world’s bananas are produced in India with an estimated annual output of 13.5 million tonnes. After fruit production, the trunk of the banana plant i.e. the pseudo stem is thrown as agricultural waste to a great extent. These pseudo stems can be effectively utilized in production of banana fibres as annually, about 1.5 million tonnes of dry banana fibres can be produced for the outer sheath of pseudo stem. Banana fibre has good specific strength properties comparable to those of conventional material like glass fibre. The material has a lower density than glass fibres. Useful applications of such fibres would regularize the demand which would be reflected in a fall of prices. Banana fibres have high strength, light weight, smaller elongation, fire resistance quality, strong moisture absorption quality, great potentialities and biodegradability.

1.4. PROBLEM STATEMENT

Agriculture waste is a raw material for industry nowadays. It does not only economical but also can lead to air pollution such as global warming (Srinivasan K, 2010). Agriculture waste material usually disposed into landfill or dispose by open burning that may lead to air pollution.Banana is a quite common material abundantly used. After riping out the banana the disposal of its stem leads to environmental issues.

This waste material can be used to increase the strength of concrete. The source of natural fibre as cementitious material are found in plant and they are readily environmental friendly as well as cheap. In addition, natural fibres such as banana have an excellent potential to improve the properties of materials, and could be used effectively to improve the performance of concrete.

1.5. APPLICATIONS

Banana is cultivated in about 2, 30,000 hectares of land and the fibre yield is around 8.7 lakh toned. Though fibre extraction is not done on any large scale at present, banana fibres are reported to have been spun on the jute spinning machinery and used hand bags and other fancy articles. Most of the Banana fibers produced today is used for ropes and cordage. The resistance of the fibre to the sea-water and its natural buoyancy has created a ready market for it in the manufacture of shipping cables. It is also widely used for making power transmission ropes and cordage, wall drilling cables, fishing nets, lines and other types of cordage. Bast fibers such as flax, jute, hemp, and pineapple etc plant fibers are all made up of thick walled cell tissue and they are bonded together by natural gums and support the branches, stems, leaves and fruits. Although banana plants and fibers are available in tropical regions in abundance, their application potential has not been exploited fully. At present, other companies make the limited application of banana fiber, for example, in making ropes, mats, and some other fields such as the composite materials. In recent years, more and more plant fibers were considered to be "environmentally friendly" fiber sources, and many countries 51 are emphasizing the utilizing of these fibers. The best thing about these fabrics is that they are biodegradable, finally broken down into water and carbon dioxide by microorganisms in the soil. Innovation sees no limit and Indian consumers can expect something big coming up in the textile industry like fabrics and textiles woven from fine quality banana fibre. Several studies carried out on blending revealed that the studies were carried out on cotton with various natural and synthetic fibers with a view to impart value addition. In the present investigation banana fibres were blended with cotton and jute fibres to make banana blended fabrics and further evaluation of the fabric properties are also carried out. In the recent past, banana fiber had a very limited application and was primarily used for making items like ropes, mats, and some other composite materials. With the increasing environmental awareness and growing importance of eco-friendly fabrics, banana fiber has also been recognized for all its good qualities and now its application is increasing in other fields too such as apparel garments and home furnishings. However, in Japan, it is being used for making traditional dresses like kimono, and kamishimo since the Edo period (1600-1868). Due to its being lightweight and comfortable to wear, it is still preferred by people there as summer wear. Banana fiber is also used to make fine cushion covers, Neckties, bags, table cloths, curtains etc. Rugs made from banana silk yarn fibers are also very popular world over.

1.6. RESEARCH SIGNIFICANCE

Fibre is a reinforcing material possessing certain characteristic properties to be used in concrete. Concrete containing fibrous material which increases structural integrity. Short discrete fibres are uniformly distributed and randomly oriented in concrete to increase the integrity. Banana Stem Fibre is mainly use in Shotcrete but can also be used in Normal Concrete. Fibres are normally used in concrete to control plastic shrinkage cracking. They also lower permeability of concrete and thus reduce bleeding of water. Some types of fibres produce greater impact, abrasion and shatter resistance in concrete.

1.7. SCOPE OF WORK

There are two prominent research issues associated with the use of banana fibre in cement concrete. First is the hydrophilicity of natural fibre. The high hydrophilicity of natural fibre makes the wet concrete stiff and non-workable due to gradual absorption of water from the wet concrete mixture. The second research issue is the agglomeration of the chopped banana fibre during concrete mixing leading to inhomogeneous fibre dispersion in the concrete matrix.

Hence the major challenges in this project is to

1. Reduce hydrophilicity of banana fibre by surface modification

2. Reduce fibre agglomeration in concrete matrix
3. Formulate a novel mixing technique and fabrication of banana fibre reinforced cement concrete/mortar having improved physical and mechanical properties.

1.8. OBJECTIVE

The general objective of this study is to investigate the compressive strength of concrete banana fibre as cementitious to produce high strength concrete. The specific objectives of this study were:

1. To evaluate the suitability of short banana fibre as a reinforcing agent in cement concrete/mortar.
2. Optimization of length of short banana fibre and its loading in cement matrix.
3. Modification of banana fibres with chemicals and characterization of modified banana fibre.
4. Mixing and casting of untreated and chemically modified banana fibre reinforced cement concrete/mortar.
5. Physical, Mechanical and Structural characterization of fabricated cement concrete/mortar.

1.9. TASKS AND DELIVERABLES

Tasks of this project are:

1. Development of modified banana fibre: Modification of banana fibre with suitable chemical.
2. Development of unmodified and modified chopped banana fibre reinforced cement concrete composite.
3. Prototype development of modified banana fibre reinforced cement concrete products.

1.10. RESEARCH METHODLOGY

The proposed research methodology is schematically presented in Fig.1.1.

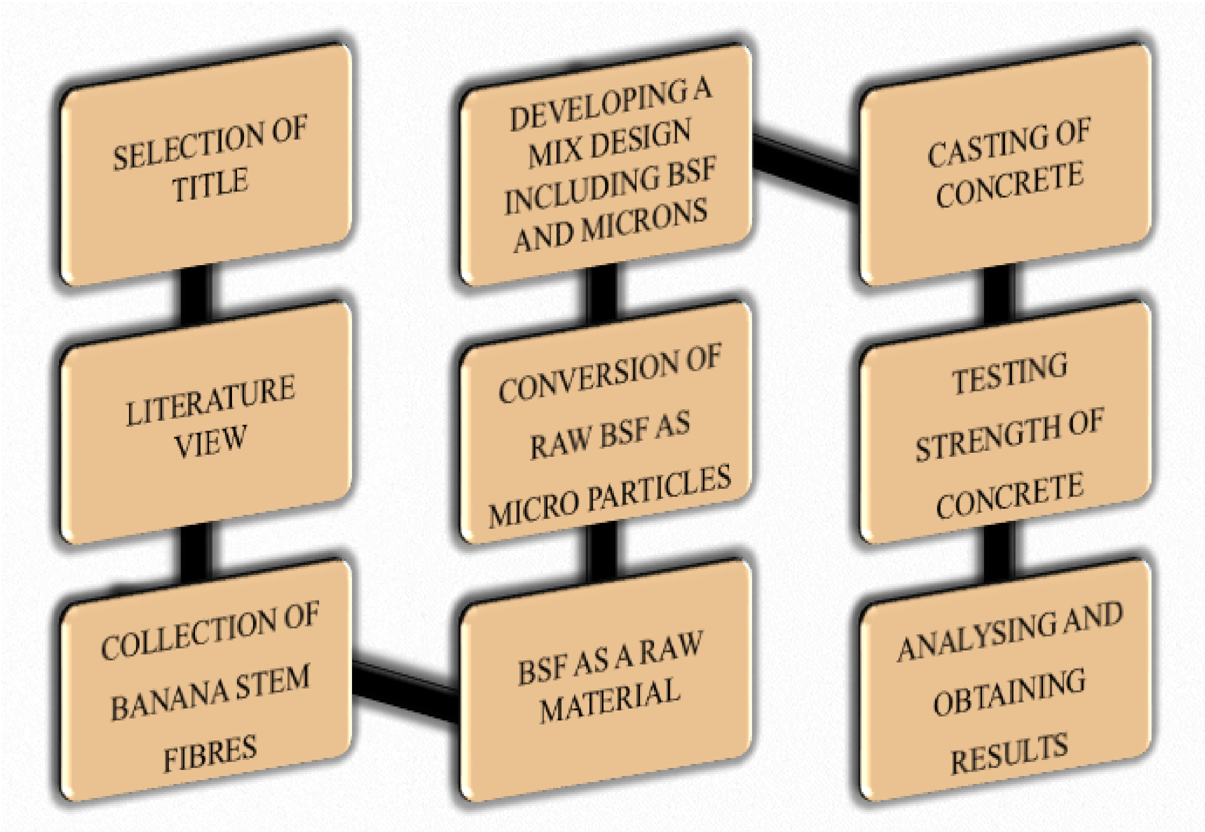

Fig.1.1.Research Methodology

CHAPTER 2

LITERATURE REVIEW

2.1. GENERAL

Dimensional instability of plant-based natural fibres which is traceable to the propensity of these fibres to readily absorb and loss water under varying humidity conditions has a significant influence on fibre-cement matrix bond behavior. Consequently, various processes such as silane treatment, acetylation, acrylation, alkali treatment, pulping, hornification etc. has been explored by researchers as a means of reducing dimensional instability of plant based fibres. Pre-treatment of fibres with alkalis can remove natural land artificial impurities and break down fibre bundle into smaller fibres, thereby increasing the effective surface area. It alsoproduces a rough surface topography which can offer higher resistance to the pull-out of the fibre from the matrix. It reported improvements in the fibre matrix adhesion of acetylized and silane surface treated natural fibres; they attributed this to the reduced moisture absorption property of the fibres. Li et al. [9] observed improved fibre-cement paste bond and toughness in alkalized coir fibre reinforced cement mortar. He also observed that alkali treatment not only improves the fibre strength, it also enhances the fibre matrix adhesion in a positive way. Other modification approaches were also explored by researchers. Findings indicated that the immersion of sisal and coconut fibres in a silica fume slurry before their addition to cement mortar was very effective in reducing the embrittlement of the composite.

Generally the addition of synthetic fibers to cement composite enhances toughness, ductility, and impact resistance properties. Similar results have been reported for some cement composite containing plant based natural fibers. Toughness increases as the fiber volume increases the optimum flexure strength is 8% - 10%. Improvement in toughness is due to increased frictional stress and pulled out force induced by swollen fibers. Moisture content has a significant effect on the mechanical strength of plant based natural fiber. While water saturation of specimen causes 18% - 51% of reduction in flexural strength and lower toughness.

Plant based fibers could absorb significant quantity of water. They consists of cellulose, hemi cellulose, lignin extractives and ash. Cellulose, Hemi cellulose and lignin are mainly responsible for bond behavior and degradation of natural fibers in composite. The strength and stiffness of banana stem fibers depends on the cellulose content and the orientation of micro fibrils in the cell wall. The chemical and mechanical properties is influenced by fiber extraction method.

Modulus of elasticity of banana stem fiber in flexure has been studied. As fiber content increases the modulus of elasticity decreases.

Some studies have shown that plant-based natural fibres have a negative effect on the hydration of cement composites. He observed delayed setting time and reduced heat of hydration in sugarcane bagasse fibre reinforced cement composites. They attributed this occurrence to water soluble sugars formed as a result of the alkaline hydrolysis of lignin and partial solubilization of hemicellulose contained in these fibres. Likewise, Marie- ange Arsene[1] suspected that the delayed setting time they recorded in bamboo flakes reinforced Portland cement matrix was caused by high quantities of sugars in the fibre. The dissolution of these soluble sugars produces calcium compounds in the cement matrix. These compounds lower cement hydration temperature and delay the formation of hydration products. Similar delay in the setting time of cement composites containing hemp fibres was also observed , and this was attributed to the presence of pectins contained in these fibres, which acted as a calcium silicate hydrate (CSH) growth inhibitor. In a more recent study, Fan et al. [1] suggested that the reduced cement hydration in wood cement composites they investigated was caused by carbohydrates and hemicelluloses contained in the wood. He were of the opinion that delay in hydration depends on the concentration of soluble sugars in mixtures, and could be mitigated through the addition of pozzolan. The negative effect of plant-based natural fibres on cement hydration could also be reduced through the use of pre-treated fibres containing low amounts of lignin in cement composites. Furthermore, increased curing temperature, the addition of chemical accelerators and supplementary materials with high surface area such as finely ground limestone powder to mixtures could also help in enhancing early age hydration.

2.2. CONCRETE MATERIALS

Concrete is the composite material that is compose by mixing several raw materials such as water, cement, course aggregate, fine aggregate and sometimes admixture. This raw material can be found naturally on earth and have several advantages.

According to R Srinivasan (2010), the major material used in construction through the world is ordinary Portland cement (OPC). 80% - 90% of the total production comes from OPC. OPC was made up from five different raw materials. These are alumina, silica, lime, iron, and also gypsum. This raw material went through three different processes mainly, milling process, manufacturing process, and also burning process.

The most important function of aggregate is to assist in producing workability and uniformity of concrete and to provide binder to the concrete. This material usually found near river bed and the size of course aggregate commonly use is 20mm nominal maximum size. (Srinivarsan R, 2010). By using natural fiber ash as cementitious material, it can produce better mixes with less aggregate quantities (Ellie Award, 2010). This aggregate is used to create a good concrete strength that accepts the shrinkage tension and to give the concrete with less shrinkage. Aggregate is one of material that make up majority ingredient in concrete mixture. For example, sand, gravel, crushed aggregate and also course aggregate.

Water is the most important material use in concrete making. Usually water is used to bind all the materials together until concrete is hardened. Too much water will reduce the strength of concrete while too little water can lead to high workability of concrete. Therefore, water cement ratio is important in concrete mixing because it can influence the grade of concrete.

2.3. NATURAL AGRICULTURE WASTE

There are two processes to dispose agriculture waste materials. Usually this material was disposed into landfill or by open burning. These processes were harmful for our environment because it can lead to air pollution and global warming (Girisha C, 2012). From previous study, it is proved that agriculture waste can help to enhance the strength of concrete in form of fiber or ash (Elizabeth O, 2013).

Large quantities of waste materials can lead to social and environmental problems. Concrete technology need to be conducted based on this issue. Several researchers have been conducted to study on cementitious agriculture wastes. For example, coconuts, sugar canes, vegetables, corn cobs and others. The used of waste materials also can reduce the cost of concrete production, by reducing the quantity of cement used (Elizabeth O, 2013).

According to Samrat Mukhopadhyay (2008), a lot of researches have been conducted to study the use of natural fiber ash to produce high quality of concrete. Banana fiber ash is one of the potential materials to use because it has cementitious and also mechanical properties. A lingo-cellulose fiber is obtained from banana stem and it is the best fiber which it has relatively good in mechanical properties. In this industry, there were many researchers conducted in investigating the natural fiber such as wood, sisal, bamboo, coconut, and other organic fiber to produce high strength concrete (Ellie Award, 2010).

2.4. JUSTIFICATION FOR WORK

From the above studies we have concluded that on decreasing the size of the fibre the concrete strength may increase like its behavior in concrete earth blocks. Compared to all other banana species Nendran has maximum cellulose content which leads to increase bonding behavior in concrete. We chose 0.3% and 0.5% fibre in concrete from the above studies. Decay characteristics has been reduced by alkali (NaOH) treatment on fibre.

CHAPTER 3

METHODOLOGY

3.1. CHARACTERISTICS OF BANANA FIBRES

Banana fiber has its own physical and chemical characteristics and many other properties that make it a fine quality fiber.

1. Appearance of banana fiber is similar to that of bamboo fiber and ramie fiber, but its fineness and spin ability is better than the two.
2. The chemical composition of banana fiber is cellulose, hemicellulose, and lignin.
3. It is highly strong fibre and smaller elongation.
4. It has somewhat shiny appearance depending upon the extraction & spinning process.
5. It is light in weight.
6. It has strong moisture absorption quality. It absorbs as well as releases moisture very fast.
7. It is bio- degradable and has no negative effect on environment and thus can be categorized as eco-friendly fiber.
8. Its average fineness is 2400 N-m.
9. It can be spun through almost all the methods of spinning including ring spinning, open-end spinning, bast fiber spinning, and semi-worsted spinning among others.

3.2. FTIR SPECTROSCOPY

FTIR-Fourier Transform Infra Red Spectroscopy.

The banana fibers used in this work were extracted from the pseudo-stem of a banana plant of the specimen (Musa balbisiana) whose fruits called "banana prata" (silver banana) which are very much appreciated in Brazil. Fig.3.1 illustrates the banana plant, the pseudo-stem and corresponding fibers.

Fig.3.1. Banana Plant, Pseudo-stem and Extracted Fibres

The supplied banana fibers were cleaned in water and dried in the stove at 60°C for 2 hours. In short, the mean equivalent fiber diameter was measured by profile projector and found as 0.18 mm. The average density was calculated as 0.85 g/cm^3.

The FTIR analysis was conducted in a model IR PRESTIGE 21-FTIR-SHIMADZU. The banana fiber sample was prepared according to the following procedure. First, the banana fibers were milled in a ceramic pestle until powder, which was then mixed with KBr particles, suitable for FTIR analysis. The compound was then pressed to produce a film in the condition required for testing. The FTIR Spectra of BSF is shown in fig.3.2.

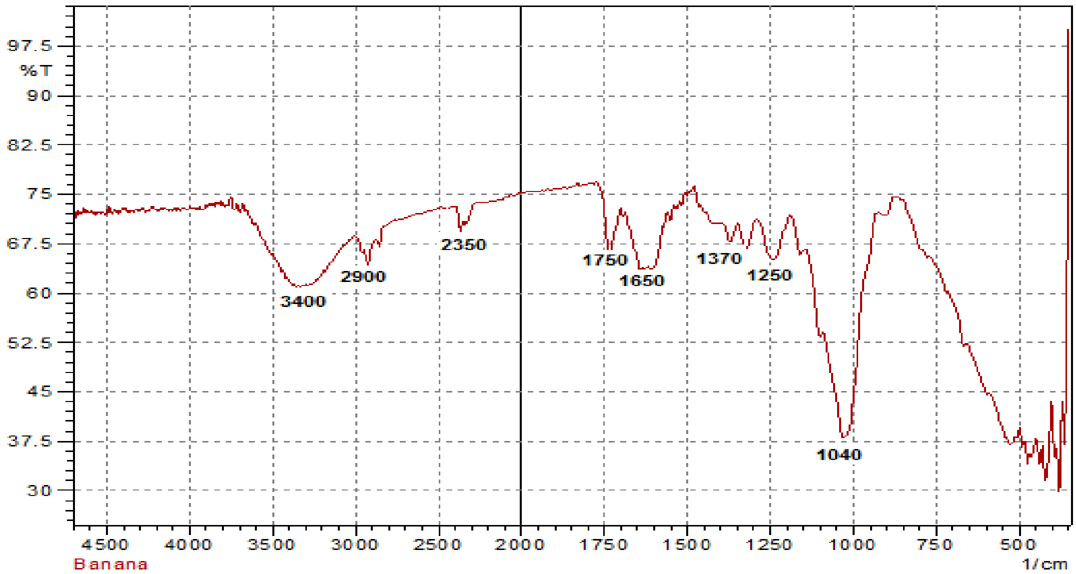

Fig.3.2. FTIR Spectra of common Banana Fiber (Musa balbisiana)

At this point of the present investigation, it is only possible to speculate that the relatively small O-H stretching band at 3400 cm^{-1} might be associated with limited reactive efficiency of the hydroxyl at the banana fiber surface. This could represent facility for water desorption as well as hemicellulose and lignin decomposition. The accentuated band at 1040 cm^{-1} might represent a difficult for ether radicals to decompose.

3.3. SURFACE TOPOGRAPHY STUDIES OF BANANA FIBER BY SEM

The surface topography of banana fibers was investigated to examine the effect of chemical treatment upon the fiber surface using a scanning electron microscope (SEM). The powdered samples were coated with a thin layer of gold and scanning electron micrographs of fiber samples were taken in TESCAN Vega LSV SEM. SEM micrographs indicate a significant change in surface topography after chemical treatment. The surface of raw banana fiber was smooth with multicellular nature, whereas rough surface morphology with fragments and better fibril separation were observed due to alkali treatment. This phenomenon may be attributed to the leaching of surface impurities, non-cellulosic materials, inorganic substances and wax. The rough surface obtained after alkali treatment may improve the adhesion between fiber and matrix when used in reinforcing composite materials. After modification with polymer latex a thin coating of polymer was observed on banana fiber surface. The SEM image of a typical banana stem fibre as shown in fig.3.3.

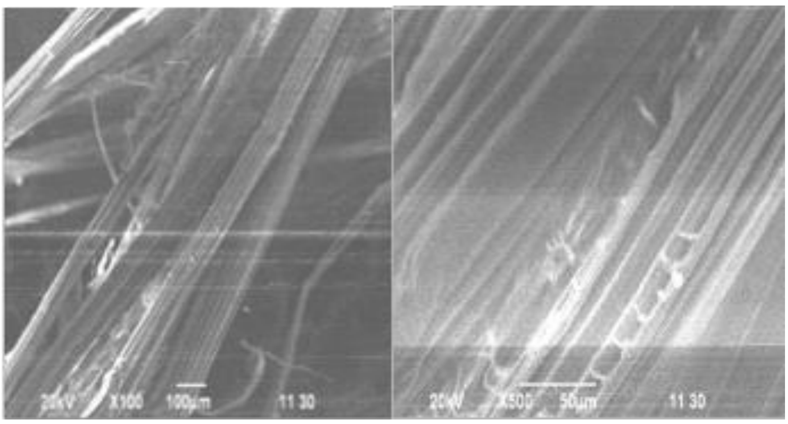

Fig.3.3. SEM Image of Banana Stem Fibres

3.4. ALKALI TREATMENT

Alkali treatment increases surface roughness resulting in better mechanical bonding and the amount of cellulose exposed on the fibre surface. This increases the number of possible reaction sites and allows better fibre wetting. The possible reaction of the fibre and sodium hydroxide (NaOH) is as follows

$$\text{Fibre-OH} + \text{NaOH} \Longrightarrow \text{Fibre-O-Na}^{+} + H_2O$$

The banana fibres were cleaned and immersed in the 6% solution for 2h at room temperature and thoroughly washed by immersion in the clean water tank to remove non reacted alkali until fibres are alkali free. They were next rinsed under running water and filtered. The filtered fibres were then dried in an oven at 80°C for 24 hours. This treatment is shown in fig.3.4

Fig.3.4. Alkali (NaOH) treatment of Banana Stem Fibres

By boiling in optimum NaOH solution, lignin can be accessed and removed that allows rearrangement of molecules, which increases crystallinity and crystallite sizes. Available literature reveals that alkali treatment removes the binding materials, depending on the treatment time, concentration of alkali used, temperature of treatment, liquor ratio, etc. Study on effect of alkali concentration on fibre yield and other properties of fibre has already been reported.

There are clear changes in fibre composition due to alkali treatment under optimum conditions. The removal of lignin from mechanically extracted banana fibre is at least 40% in the optimum conditions. There is 20% increase in the cellulose content. The hemicellulose contents are also reduced by half of the actual content. The surface morphology reveals that there is a separation in the fibre bundles. There is an increase in density due to removal of the low denser hemicellulose and lignin contents. There is an increase in moisture regain of the fibres, thus making the fibre more hydrophilic and suitable for the textile applications. It is a drawback when fibre is used as reinforcement in composite application since it reduces the wettability of the resin. The single fibre strength and the crystallinity of the fibres have improved, which is an advantage in both textiles as well in composite applications. The colour has become darker and the hue has increased which is a drawback from the aesthetic point of view. The tensile strength of raw and treated BSF are presented fig.3.5.

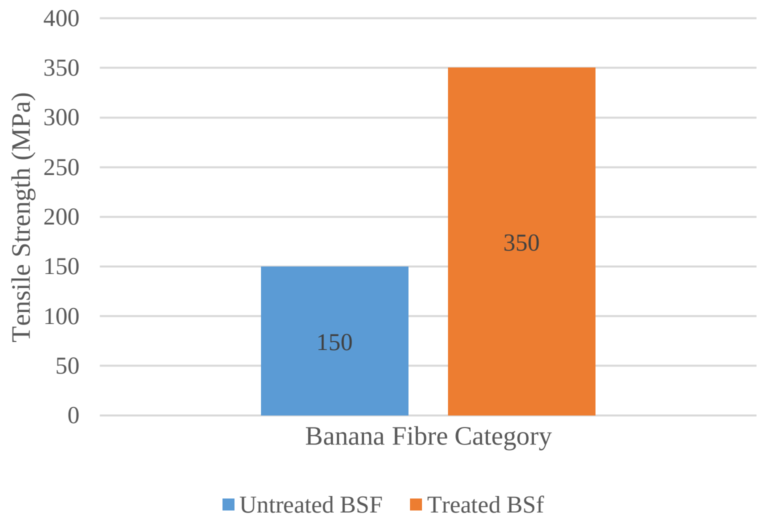

Fig.3.5. Tensile Strength of Raw and Alkali Treated BSF

3.5. MATERIALS

Banana stem is collected from Neelambur, Coimbatore. Nendran species is taken for project work because it has high fibre (cellulose) content among other banana species. Banana Stem Fibre (Nendran) is used also as reinforcing material in concrete to increase strength of concrete. Portland Pozzolana Cement (fly ash based) is used as binding material in concrete. Coarse aggregate of size 20mm is used after sieve test. River sand is used as fine aggregate to formulate concrete. River sand is used after undergoing sieve analysis and resulted in zone II.

3.6. PROPERTIES

3.6.1. CHEMICAL PROPERTIES

A chemical property is any of a material's properties that becomes evident during, or after, a chemical reaction; that is, any quality that can be established only by changing a substance's chemical identity. Simply speaking, chemical properties cannot be determined just by viewing or touching the substance; the substance's internal structure must be affected greatly for its chemical properties to be investigated. When a substance goes under a chemical reaction, the properties will change drastically, resulting in chemical change. However, a catalytic property would also be a chemical property. The chemical constituents of BSF are found by conducting FTIR, SEM. The results are presented in Table.3.1.

Table.3.1. Chemical Constituents of Nendran Banana Stem Fibres

CONSTITUENTS	PERCENTAGE
Cellulose	59.22
Hemicellulose	12.09
Lignin	14.39
Pectin	2.68

3.6.2. MECHANICAL PROPERTIES

The mechanical properties of a material are those properties that involve a reaction to an applied load. The mechanical properties of metals determine the range of usefulness of a material and establish the service life that can be expected. Mechanical properties are also used to help classify and identify material as shown in Table.3.2.

Table.3.2. Mechanical Constituents of Nendran Banana Stem Fibres

Tenacity	29.98 g/denier
Fineness	17.15 %
Moisture Regain	13.00 %
Elongation	6.54 mm
Alco-ben Extractives	1.70 %

3.6.3. CHEMICAL MODIFICATION OF BANANA FIBRE

From the polar chemical nature and structure of natural fiber it appears that such fibers can interact with polar nature of cement concrete. This concept justifies the reinforcing action of banana in cement concrete. Simultaneously due to polar character of natural fiber, viz., banana, it shows hydrophilic character. Such hydrophilicity might lead to depletion of water from the wet concrete mix as well as it might degrade in due course of time as a result of microbial attack. Inorder to overcome such shortcomings banana fibers need suitable physicochemical modification before incorporation in concrete matrix. It was anticipated that after modification with alkali and other chemical constituents, microbial degradation of banana fiber can be either delayed or prevented.

3.7. CONVERSION OF FIBRES TO MICRON SIZE

Ball mill is the key equipment for grinding after the crushing process, is an efficient tool for grinding various kinds of materials into fine powder. The ball mill used in the experiment is shown in the fig.3.6.

3.7.1. FEATURES OF BALL MILL:

1. Double row self-aligning bearings, replace the plain bearings to reduce friction, reduce energy consumption, the mill is easy to start.
2. Large application range, simple structure and convenient maintenance
3. Inertial impaction equipment running smoothly, and reduce the mill downtime parking maintenance time, improve efficiency.
4. Various barrel lining and grinding media, excellent corrosion resistance.
5. Large-caliber material inlet and outlet, large capacity.

Fig.3.6. Ball Mill

3.7.2. WORKING PRINCIPLE OF BALL MILL

A Ball Mill grinds material by rotating a cylinder with steel grinding balls, materials enter the first cabin of ball mills via the feeding device across the hollow shaft uniformly, into the compound empty axis spiral. In the first cabin, which has the ladder liner and corrugated liner with multiple size steel balls, will be lifted to the certain height in the effect of the centrifugal force produced by the rotating cylinder. Then the balls fall to impact and grind the materials. After the rough grinding process, materials enter the second cabin through the single layer cabin separating board. Steel balls in the second cabin which will grind materials. The finished powder materials are discharged from the unloading plate, thus finishing the grinding process.

Extracted fibres after chemical treatment are cut to 1cm size. These fibres are grind to micron size using ball mill. Tungsten balls are used for grinding. Particle to ball size ratio is 1:10. The speed of the ball mill is 250rpm. Fibre is ground for 2 hours to convert the particle size to a range of 100µm-200µm.

3.7.3. PARTICLE SIZE ANALYSIS

The particle size distribution was measured by a Mastersizer 3000 laser diffraction particle analyzer (Malvern Instruments Ltd.). Nendran banana stem fibre samples were dispersed in distilled water to form a liquid suspension before being added to the instrument with ultrasound. Then size of fibre particle is in the range of 100-200 µm. The different sizes of Banana Stem Fibres are shown in fig.3.7 and fig.3.8.

Fig.3.7. Banana Stem Fibre of 1cm size

Fig.3.8. Banana Stem Fibre of Micron (100-200 µm) size

CHAPTER 4

EXPERIMENTAL STUDY

For any research the basic physical properties of materials are essential to carry out the detailed investigation. In this study also the following properties are studied.

4.1. SPECIFIC GRAVITY OF COARSE AGGREGATE

Specific gravity can be measured in a number of value ways. The following calculation involving the use of the pycnometer is instructive. A pycnometer is simply a bottle which can be precisely filled to a specific, but not necessarily accurately known volume, V.

Weight of empty pycnometer (W_1)	=	646 g
Weight of pycnometer + coarse aggregate (W_2)	=	898 g
Weight of pycnometer + coarse aggregate + Water (W_3)	=	1705 g
Weight of water (W_4)	=	1537.5 g
Weight of soil in the pycnometer ($W_2 – W_1$)	=	252 g
Weight of equal volume of water ($W_4 – W_1$) - ($W_3 – W_2$)	=	84.5 g

Specific gravity (G) $= \dfrac{(W_2 - W_1)}{(W_4 - W_1) - (W_3 - W_2)}$

$= \dfrac{\mathbf{252}}{\mathbf{84.5}}$

$= 2.75.$

Hence the specific gravity of coarse aggregate is **2.75**

4.2. SPECIFIC GRAVITY OF FINE AGGREGATE

Weight of empty pycnometer (W_1)	=	646 g
Weight of pycnometer + fine aggregate (W_2)	=	860 g
Weight of pycnometer + fine aggregate + Water (W_3)	=	1667 g
Weight of water(W_4)	=	1537.5 g
Weight of soil in the pycnometer ($W_2 – W_1$)	=	214 g
Weight of equal volume of water ($W_4 – W_1$) - ($W_3 – W_2$)	=	84.5 g

$$\text{Specific gravity (G)} = \frac{(W_2 - W_1)}{(W_4 - W_1) - (W_3 - W_2)}$$

$$= \frac{\mathbf{214}}{\mathbf{84.5}}$$

$$= 2.74$$

Hence the specific gravity of fine aggregate is **2.74**

4.3. WATER ABSORPTION TEST ON COARSE AGGREGATE

The varying moisture contained on aggregates is one of the major causes of inconsistency in batching concrete from one batch to another. Moisture content can have dramatic effect on the concrete compressive STRENGHT and DURABILITY because it has a great influence on the WATER/CEMENT ratio. Knowing the moisture content on GRAVEL, it allows the Concrete Batch Controller to accurately calculate and adjust the amount of water to be added to the mix. This test is shown in fig.4.1.

Fig.4.1. Water Absorption Test on Aggregate

Weight of dry coarse aggregate, W_1 = 2000 g

Weight of saturated specimen ,W_2 = 2030 g

Weight of absorbed water, ($W_3=W_2-W_1$) = 30 g

% Of water absorption = $\left(\frac{W3}{W1}\right)\times 100$

$= \left(\frac{30}{2000}\right) \times 100$

= 1.5%

Hence percentage of water absorption of coarse aggregate is **1.5%**

4.4. FLAKINESS INDEX OF COARSE AGGREGATE

Flakiness Index is the percentage by weight of particles in it, whose least dimension (i.e. thickness) is less than three-fifths of its mean dimension. Flaky particles may have adverse effects on concrete. For instance, flaky particles tend to lower the workability of concrete mix which may impair the long-term durability. The calculations are shown in Table.4.1.

Nominal size of aggregate = 20 mm.

Table.4.1.Calculation of Flakiness Index of Coarse Aggregate

Size of Aggregates		Weight fraction Consisting Of Atleast 200 Pieces	Thickness Gauge Size, Mm	Weight Of Aggregates In Each Fraction Passing Thickness Gauge, G
Passing through IS Sieve , mm	Retained On IS Sieve ,mm			
63	50	823.5	33.9	141.5
50	40	1229.5	27	-
40	31.5	1484	19.5	39.5
31.5	25	1232	16.95	62.5
25	20	1220.5	13.5	91
20	16	713	10.8	89
16	12.5	211.5	8.55	16.5
12.5	10	46.5	6.75	3
10	6.3	22	4.89	2.5
		$\sum W$ =6982.5		$\sum X$=445.5

Flakiness index $= \frac{\sum W}{\sum X} \times 100$

$= (\frac{445.5}{6982.5}) \times 100$

=6.38%

Hence flakiness index of coarse aggregate is **6.38%**

4.5. ELONGATION INDEX OF COARSE AGGREGATE

Elongation Index is the percentage by weight of particles in it, whose largest dimension (i.e. length) is greater than one and four-fifths times its mean dimension. Elongated particles may have adverse effects on concrete mix. For elongated particles tend to lower the workability of concrete mix which may impair the long-term durability. The calculations are shown in Table.4.2.

Table.4.2.Calculation of Elongation Index of Coarse Aggregate

Size of Aggregates		Weight Fraction Consisting Of Atleast 200 Pieces	Length Gauge Size, mm	Weight of Aggregates in each fraction passing length gauge, g
Passing through IS Sieve , mm	Retained on IS Sieve ,mm			
63	50	823.5	823.5	-
50	40	1229.5	81	186
40	31.5	1484	58	-
31.5	25	1232	-	-
25	20	1220.5	40.5	74
20	16	713	32.4	155
16	12.5	211.5	25.5	58
12.5	10	46.5	20.2	3
10	6.3	22	14.7	4.5
		$\sum W = 6982.5$		$\sum Y = 480.5$

Elongation index $= \frac{\sum W}{\sum Y} \times 100$

$= (480.5/6982.5) \times 100$

$= 6.88\%$

Hence elongation index of coarse aggregate is **6.88%**

4.6. CONCRETE MIX DESIGN

Mix design for M20 concrete is as follows

STIPULATIONS FOR PROPORTIONING

Grade designation	:	M 20
Type of cement	:	PPC 53 grade conforming to IS 8112
Maximum nominal size of aggregate	:	20 mm
Minimum cement content	:	320 kg/m^3
Maximum water cement ratio	:	0.5
Workability	:	75 mm (slump)
Exposure condition	:	Severe
Method of concrete placing	:	Pumping
Degree of supervision	:	Good
Type of aggregate	:	Crushed angular aggregate
Maximum cement content	:	450 Kg/m^3

TEST DATA FOR MATERIALS

Cement used	:	PPC 53 Grade conforming to IS 8112
Specific Gravity		
Cement	:	3.15
Coarse aggregate	:	2.74
Fine aggregate	:	2.75
Water absorption		
Coarse aggregate	:	0.5%
Fine aggregate	:	1%
Free (surface) moisture		
Coarse aggregate	:	Nil
Fine aggregate	:	Nil
Sieve analysis		
Coarse aggregate	:	20 mm
Fine aggregate	:	Conforming to Table 4 of IS 383

CALCULATION OF MIX DESIGN

Target strength for mix proportioning

$$f'_{ck} = f_{ck} + 1.65\ s$$

where,

f'_{ck} = target average compressive strength at 28 days,

f_{ck} = characteristic compressive strength at 28 days, and

s = standard deviation

From Table 1 of **IS 10262:2009** , standard deviation ,s = 4N/mm^2.

Therefore, Target strength = 20 + 1.65×4 =26.6 N/mm^2.

Selection of water cement ratio

From Table 5 of **IS 456**, maximum water cement ratio=0.5

Selection of water content

From Table 2 of **IS 10262:2009** maximum water content for 20mm aggregate

= 186 litre(for 25 to 50 mm slump range)

Estimated water content for 75 mm slump = 186 + (3/100)×186

=192 litre

Calculation of Cement Content

Water cement ratio = 0.5

Cement content =192/0.5 = 385 kg/m^3

From Table 5 of IS 456, minimum cement content for severe exposure condition

= 320 Kg/m^3.

385 Kg/m^3 > 320 Kg/m^3, Hence OK.

Proportion of Volume of Coarse Aggregate and Fine Aggregate Content

From Table 3, volume of coarse aggregate corresponding to 20 mm fine aggregate (Zone II) for water cement ratio of 0.5 = 0.60.

In the present case water cement ratio is 0.5.Therfore, volume of coarse aggregate is required to be increased to decrease the fine aggregate content. As the water cement ratio is lower by 0.10, the proportion of volume of coarse aggregate is increased by 0.02(at the rate of +/- 0.01 for every ±0.05 change in water cement ratio).Therefore, corrected proportion of volume of coarse aggregate for the water cement ratio of 0.5 = 0.62.

Note : In the case of coarse aggregate is not angular one, then also volume of coarse aggregate may be required to be increased suitably, based on experience.

For pumpable concrete these values should be reduced by 10 percent.

Therefore, volume of coarse aggregate = 0.62 ×0.9=0.56.

Volume of fine aggregate content= 1-0.56=0.44.

MIX CALCULATIONS

The mix calculations per unit volume of concrete shall be as follows:

Volume of concrete = 1 m^3.

Volume of cement $= (\frac{\text{Mass of cement}}{\text{Specific gravity of cement}}) \times (\frac{1}{1000})$

$= (\frac{384}{3}) \times (\frac{1}{1000}) = 0.128$ m^3.

Volume of water $= \left(\frac{\text{Mass of water}}{\text{specific gravity of water}}\right) \times \left(\frac{1}{1000}\right)$

$= \left(\frac{192}{1}\right) \times \left(\frac{1}{1000}\right)$

$=0.192\ m^3$.

Volume of all in aggregate = 1- (0.128 + 0.192)

= 0.68 m^3.

Mass of coarse aggregate = e × Volume of coarse aggregate × Specific gravity of coarse aggregate × 1000

= 0.68 × 0.56 × 2.74 × 1000

= 1028.16 Kg.

Mass of fine aggregate = 0.68 × 0.44 × 2.75 × 1000

= 807.84 Kg.

Mix proportions

Cement = 384 Kg/m^3.

Water =192 litre.

Fine aggregate =1028.16 Kg/m^3.

Coarse aggregate =807.84 Kg/m^3.

Water cement ratio =0.5

Mix ratio = **1:2.1:2.6**

4.7. MIX PROPORTION

Based on previous researches, two mix proportions are concluded one in fibre and other in micron where chosen. They are,

M1-Normal M20 concrete.

M2-Addition of 0.3% banana fibre in concrete.

M3-Addition of 0.5% banana fibre in concrete.

M4-Addition of 0.3% fibre in micron form in concrete.

M5-Addition of 0.5% fibre in micron form in concrete.

4.8. PREPARATION OF CONCRETE SPECIMEN

The concrete was prepared using the laboratory mixer machine.The fibre or fibre in concrete form of microns were added as per the chosen mix proportion. Inorder to find out the strength characteristics the following specimen were prepared.

a.) Concrete cube of size 150×150×150 mm

b.) Concrete cylinder of size 100 mm diameter and 200 mm height.

c.) Concrete prism of size 150×150×500 mm

The respective concrete was placed on the mould in 1/3 rd layer and each layer was compacted by giving 25 blows of 16 mm rod. The mould were removed after 24 hours and all the specimens were cured under water upto 28 days.The cast specimens are shown in figure

Fig.4.2.Casted Concrete specimen.

4.9. TESTS ON CONCRETE SPECIMEN

The following fresh concrete tests were carried out to study the workablility of concrete.

a) Slump Test
b) Compaction Factor Test
c) Vee Bee Consistometer Test
d) Flow Table Test

The following hardened concrete tests were also carried out in concrete.

a) Compressive Strength
b) Splitting Tensile Strength
c) Flexure Strength

CHAPTER 5

RESULTS & DISCUSSION

5.1. SLUMP CONE TEST

The workability of fresh concrete is determined by Slump test as per **IS: 1199 – 1959.**

Initial Reading on the graduated rod (a)	=	0 mm
Final Reading on the graduated rod (b)	=	75 mm
Time for complete Remoulding	=	15 s
Slump Measured (b) – (a)	=	75 mm
Nature of the Slump observed	=	True Slump

The Slump Value observed for the Concrete sample taken **75 mm**.

5.2. FLOW TABLE TEST

The flow and workability of the concrete is measured by using Flow Table Test.

Initial Diameter of Concrete at base (a)	=	25 cm
Final Diameter of Concrete at base (b)	=	43 cm
Spread in Diameter of Concrete (b) – (a)	=	18 cm

$$\text{Flow (\%)} = \frac{\text{Spread in Diameter of Concrete}}{\text{Initial Diameter of Concrete at base}} \text{ x } 100$$

$$= \frac{18}{25} \text{ x } 100 = 72\%$$

The Flow Percent of the Concrete Sample taken is **72%.**

5.3. COMPACTION FACTOR TEST

The workability of fresh concrete is determined by Compaction Factor test as per **IS : 1199 – 1959**

Weight of Empty Cylinder (W1) = 11.3 kg

Weight of Cylinder with Partially Compacted Concrete (W2) = 22.5 kg

Weight of the Cylinder with Fully Compacted Concrete (W3) = 23.6 kg

Weight of Partially Compacted Concrete (W4 = W2- W1) = 11.2 kg

Weight of Fully Compacted Concrete (W5 = W3- W1) = 12.3 kg

Compacting Factor (W4/W5) = 0.91

The Compaction of the Concrete Sample taken is **0.91**.

5.4. VEE BEE CONSISTOMETER TEST

The workability of fresh concrete is determined by Vee Bee Consistometer test as per **IS: 1199 – 1959.**

Initial Reading on the graduated rod (a) = 340 mm

Final Reading on the graduated rod (b) = 160 mm

Time for complete Remoulding = 4 s

The Consistency of the Concrete sample taken is **4 seconds**.

5.5. COMPRESSIVE STRENGTH OF CONCRETE

Compressive strength of a concrete is a measure of its ability to resist static load, when the latter one tends to crush it. Testing of compressive strength is the most common; many desirable characteristics of concrete are related to its strength, and hence, the compressive strength of concrete in structural design is of utmost importance. Additionally, the compressive strength gives a good and clear indication on how the strength is affected with the increase of fiber volume dosage rate in the test specimens. In IS 516, it is mentioned that the specimens for compressive strength should be 150 mm × 150 mm × 150 mm, but this only applies to the maximum aggregate size more than 20 mm while the cube specimen with 150 mm in each side , and the intensity of load is determined in megapascal qualitatively. The compression test procedure was carried out according to test method in **IS 516.**

The compressive strength of concrete as per **IS: 516 – 1959,**

Fig.5.1.Cube Specimen

Table.5.1. Compressive Strength of Concrete

Mix Proportion	Compressive Strength of Concrete in 28 days (N/mm^2)
M1	21.36
M2	25.80
M3	26.35
M4	26.20
M5	28.90

The compressive strength of regular conventional M20 concrete is increased to 25.8MPa when banana stem fibres are incorporated in concrete. It showed 21.8% increase in strength achieved at 28 days. The increase in strength may be due to enhancement of Intermediate Transition Zone. Entrapped Air Voids were reduced in concrete with Banana Stem Fibre Microns than in Concrete with Banana Stem Fibres

The compressive strength of BSF concrete increased by the % of BSF. This may be due to cellulosic fibre cement matrix bonding. The composite toughness is mainly governed by fibre matrix bonding. A well balanced interaction between cement matrix and fibre was achieved. Workability of concrete was increased by adding super plasticizer to compensate the decrease in workability due to addition of fibres. Usage of Natural Fibres reduces chloride attack, sulphide attack. Cellulose fibres reduces plastic shrinkage.

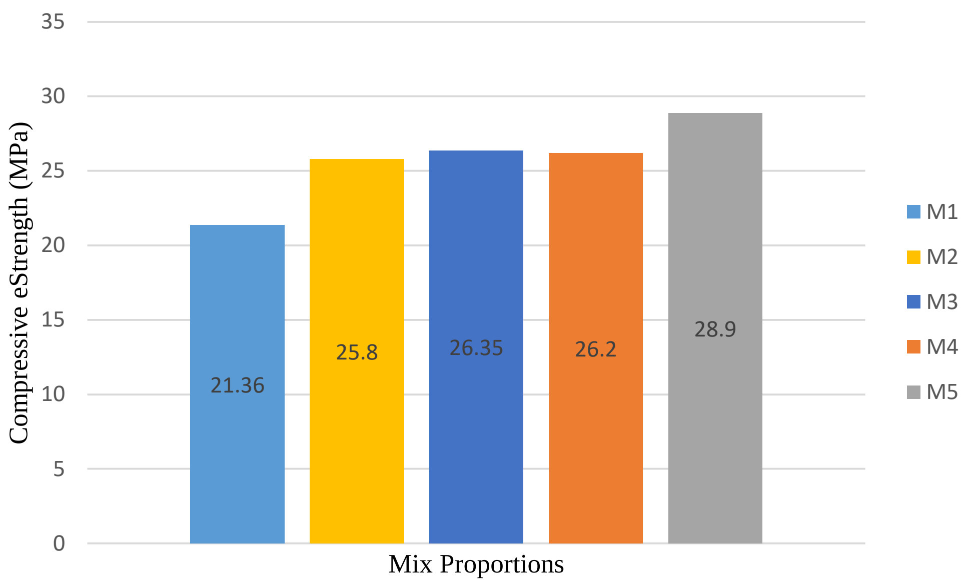

Fig.5.2. Compressive Strength of Concrete

5.6. SPLITTING TENSILE STRENGTH CONCRETE

Investigation of concrete's mechanical properties can be presented reasonably through the analysis of tensile strength. The brittleness and low tensile strength of concrete make it abortive to struggle with the direct tension. Hence, the measurement of tensile strength is obligatory to determine the load at which the concrete members may crack; therefore, the cracking is due to the tension failure. The splitting tests (sometimes referred to as split tensile strength tests) are well-known indirect tests used for determining the tensile strength of concrete. The test procedure consists of applying a compressive line load along the opposite generators of a concrete cylinder placed with its axis horizontal between the compressive planes. The splitting tensile strength test was conducted according to the test method IS 516.

The splitting tensile strength of concrete specimens are as per **IS: 516 – 1959,** Apply the load continuously and without shock, at a constant rate within, the range of 689 to 1380 kPa/min splitting tensile stress until failure of the specimen.

Table.5.2. Splitting Tensile Strength of Concrete

Mix Proportion	Splitting Tensile Strength of Concrete in 28 days (N/mm^2)
M1	2.67
M2	2.84
M3	2.85
M4	2.88
M5	2.92

The splitting tensile strength of micro stem fibres increases 9.36% when compared to normal reinforced concrete. This indicates that the splitting tensile strength of concrete increases as the fineness of fibre is increased.

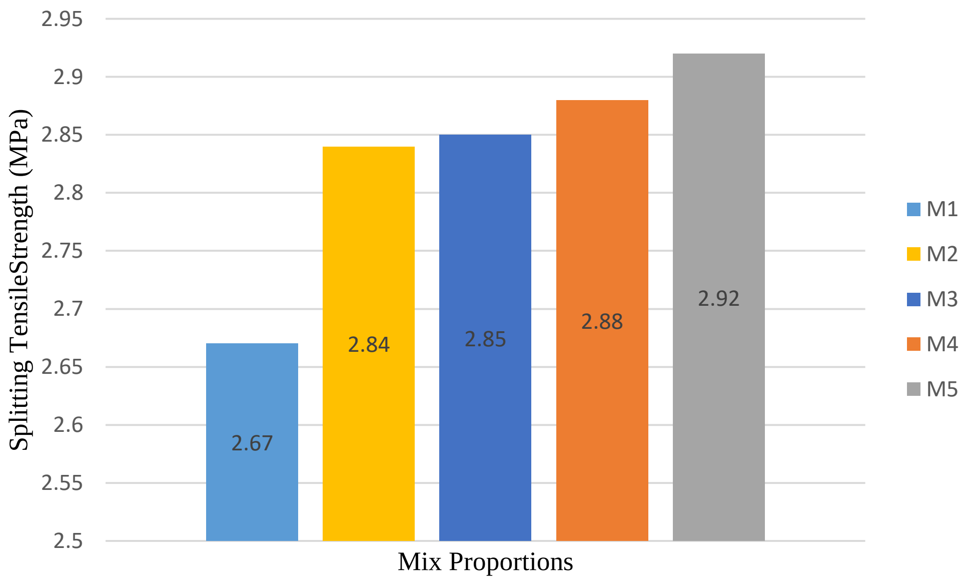

Fig.5.3. Splitting Tensile Strength of Concrete

5.7. FLEXURAL STRENGTH OF CONCRETE

Flexural strength of a concrete is a measure of its ability to resist bending, and it can be expressed in terms of modulus of rupture. Therefore, the two-point loading method was used in making flexural strength tests of concrete employing bearing blocks which ensured that forces applied to the beam was perpendicular to the face of the specimen and was applied without eccentricity. During test, the reaction was always parallel to the direction of applied force. The test procedure was carried out following the test method IS516.The distance of the loading point (l) is 133 mm and the supporting point (L) is 400 mm whereas the load was applied continuously and without any shock at a constant rate to the breaking point. Apply the load at a rate that constantly increases the extreme fiber stress 1.21 MPa/min. Finally, results were obtained in the form of total load in Kilo Newton and intensity of load in Mega Pascal. For the flexural strength, a three point bending setup was used.

Table.5.3. Flexural Strength of Concrete

Mix Proportion	Flexural Strength of Concrete in 28 days (N/mm^2)
M1	3.04
M2	3.22
M3	3.54
M4	3.12
M5	4.41

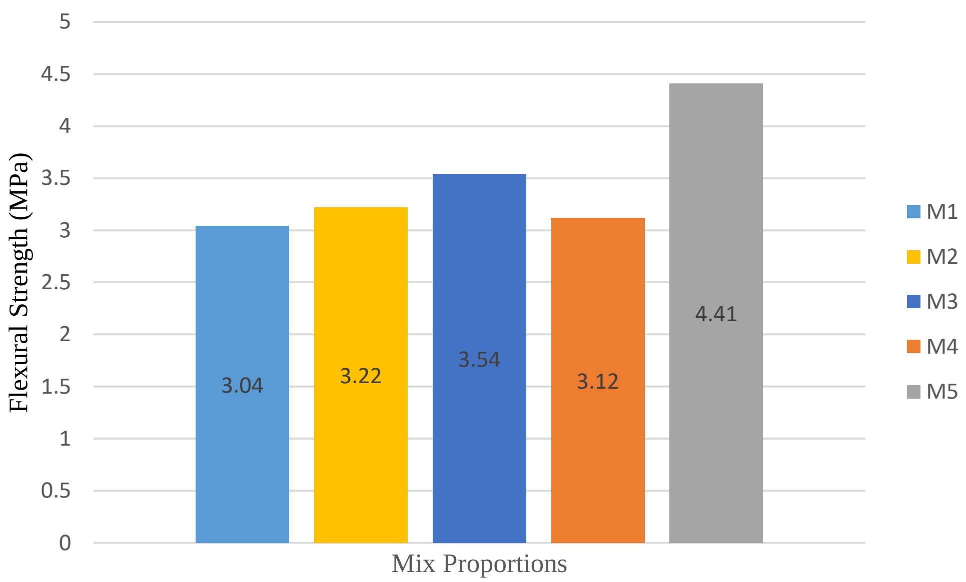

Fig.5.3. Flexural Strength of Concrete

The flexural strength of concrete was increased due to the addition of fibres. The flexural strength of micro concrete was increased by 8.08% when compared to normal concrete. From the test results, an empirical formula was obtained as $f_{cr} = 0.82\sqrt{f_{ck}}$. The IS 456 : 2000 recommends $f_{cr} = 0.7\sqrt{f_{ck}}$. Since our values were closer to the IS Codal Guidelines, it can be concluded that the study also falls in line with hw IS Codal Provisions.

CONCLUSION

Based on this study the following conclusion were drawn

1. The compression strength of banana stem fibre concrete was increased by increasing the percentage of fibres. Addition of 0.5% fibre had increased the compressive strength by 21.8%.
2. The compressive strength of banana fibre in the form of micron was also increased by increasing the percentage of micron. Addition of 0.5% micro had increased the compressive strength.
3. It is better to use fibre in the form of micron to get better compressive strength.
4. The split tensile strength of banana stem fibre concrete was increased the percentage of fibres. The split strength of micron concrete was increased by 9.36%.
5. The flexural strength of concrete was also increased as the percentage of fibre increases. The flexural strength of micro concrete was increased by 8.09%.

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