# To check the feasibility of Coconut Fiber and Polypropylene Fiber in Concrete

**Prof. Nitinkumar Jadhav[1], Omkar Gundgal[2], Chandan Ghojage[3], Bharat Jare[4], Akash Kolte[5]**

[1]*Professor, Department of Civil Engineering, Suman Ramesh Tulsiani Technical Campus, Faculty of Engineering, Kamshet, Maharashtra, India*

[2,3,4,5]*Students, Department of Civil Engineering, Suman Ramesh Tulsiani Technical Campus, Faculty of Engineering, Kamshet, Maharashtra, India*

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**Abstract -** *Concrete is the most versatile building material. Concrete has a relatively low tensile strength (compared to other building materials) and low ductility and also it is susceptible to cracking (shrinkage Cracks). A wide variety of Fibers have been used in concrete. These include steel Fiber's, glass Fiber's, synthetic Fibers and natural Fiber's – each of which lend varying properties to the concrete. For each application it needs to be determined which type of Fiber is optimal in satisfying the concrete application. The different types of synthetic Fiber's used are Polypropylene, Nylon, Polythene, Polyester and Glass Fiber's. There is currently a great deal of interest in developing the technology for using Natural Fiber material in cement. Natural Fiber's exist in reasonably large quantities all over the world and natural vegetable Fibers are produced in most developing countries. If somehow the concrete can be made strong in tension also (up to some extent) then the amount of steel reinforcement will be less. Also it will be an added advantage if compressive strength too increases. In this project one method is suggested which will help to address the above problem by adding coconut and polypropylene Fibers in conventional concrete. The project combined the use of Coconut Fiber and Polypropylene Fiber in which the natural Fiber had a greater influence on the latter. The mechanical properties of concrete were measured in terms of compressive strength and flexural strength at 7, 14, 28 days and 7 & 28 days respectively.*

***Key Words***: Synthetic Fibers, Natural Fibers, Concrete, Shrinkage Cracks, Polypropylene, Polyethene, Coconut

## 1. INTRODUCTION

Concrete is the single most widely used material in the world. In this Construction Industry, Concrete plays a major role. Concrete a composite material which is a mixture of cement, fine aggregates, coarse aggregates and water. The construction industry has made impressive progress since reinforced concrete was introduced as structural material. Fiber Reinforced Concrete can be defined as a material consisting of mixtures of cement, mortar or concrete and discontinuous, discrete, uniformly dispersed Fibers. The concept of using fibers as reinforcement is not new. Fibers have been used as reinforcement since ancient times. Historically, horsehair was used in mortar and straw in mudbricks. In the 1900s, asbestos fibers were used as secondary reinforcement in concrete. In the 1950s, the concept of composite materials came into being and fiber-reinforced concrete was one of the topics of interest. Once the health risks associated with asbestos were discovered, there was a necessity to find a replacement for the substance in concrete and other building materials. By the 1960s, steel, glass (GFRC), and synthetic fibers such as polypropylene fibers were used in concrete. Research into new fiber-reinforced concretes continues today. Fibers are typically used in concrete to control cracking due to plastic shrinkage and to drying shrinkage. They also reduce the permeability of concrete and thus reduce bleeding of water. Some types of fibers usually produce greater impact, abrasion and shatter–resistance in concrete. Generally fibers do not increase the flexural strength of concrete, and so cannot replace moment–resisting or structural steel reinforcement. Indeed, some fibers actually reduce the strength of concrete.

The amount of fibers added to a concrete mix is expressed as a percentage of the total volume of the composite (concrete and fibers), termed "volume fraction" (Vf). Vf typically ranges from 0.1 to 3%. The aspect ratio (l/d) is calculated by dividing the length of fiber (l) by its diameter (d). Fibers with a non-circular cross section use an equivalent diameter for the calculation of aspect ratio. If the fiber's modulus of elasticity is more than the matrix (concrete or mortar binder), they help to carry the load by increasing the tensile strength of the material. Increasing the aspect ratio of the fiber usually segments the flexural strength and toughness of concrete or mortar. However, fibers that are too long tend to "ball" in the mix and build workability problems. The use of natural fiber's as reinforcement in concrete (cement-sand matrix) has been comprehensively investigated in many countries. The natural fiber's reinforced material which can be used in production of building materials are presently mainly those based on coconut, bamboo, cane, henequen and sisal fibers. The main reasons for the use of natural fibers are abundantly available, comparatively cheap and biodegradable materials. Natural fibers are also claimed to offer environmental advantages such as reduced dependence on non-renewable energy/material sources, lower pollutant emissions, lower greenhouse gas emission, enhance energy recovery and energy end of life biodegradability of components. Fibers generally prevent the surface from micro cracking or shrinkage cracks which is a advantage while it also tends to keep the concrete material from getting crushed.

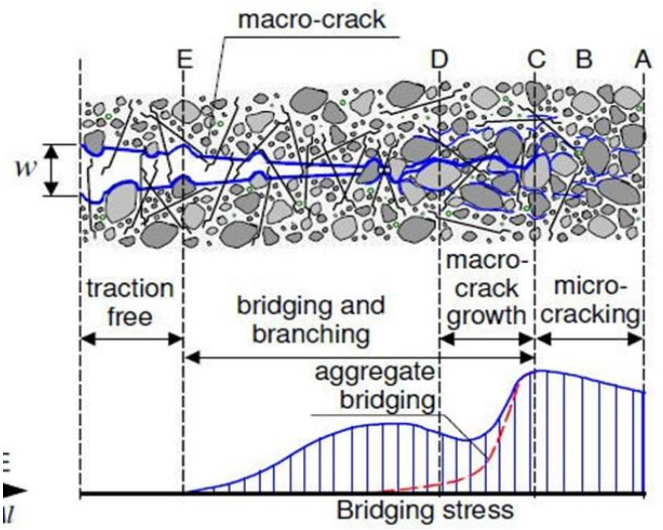


**Fig -1**: Schematic description of the effect of fibers on the fracture process in uniaxial tension (Göteborg, 2005).

## 2. Problem Statement and Scope

Concrete is very strong in compression but it is weak in tension. Hence we generally provide steel reinforcement to compensate that. If somehow the concrete can be made strong in tension also (up to some extent) then the amount of steel reinforcement will be less. Also it will be an added advantage if compressive strength too increases. In this project one method is suggested which will help to address the above problem by adding coconut and polypropylene fibers in conventional concrete.

Scope:

1. Use of Environment free Fibers.
2. Use of this Secondary Reinforcement as an important material in Concrete.

Fiber reinforced concrete as we all know are used to impart special properties to concrete that cannot be achieved by normal conventional method of mixing, placing and curing practices. The two fibers are used in such a way that they will act as a unit and impart special properties to a concrete. Their various proportions and relationship with strength will be established. It, thus, establishes a good scope for future as mixing of various fibers in small proportion may lead to a high tensile, elastic concrete. Thus, although this fiber reinforced concrete will be very good in compression, tensile and other desired properties will also increase hence may be in the coming future only fiber reinforced concrete will be used for bearing compressive, tensile and flexural load, hence minimizing the amount of reinforced steel requirements and thus may prove economical.

### 2.1 Problem Solving Approach

The experimental program consisted of various laboratory experiments to quantify the plastic properties, mechanical properties and cracking performance of FRC concrete consisting of six concrete mixtures. Additionally, the mixing procedure, concrete mixture proportions, and the preparation and storage of specimens are also described in this section. Visual observation was also carried out to inspect for any clumps and balls caused by the fiber clinging together. The compressive strength and modulus of rupture were used to evaluate the concrete mechanical properties.

## 3. Experimental Setup

A total of six concrete mixtures were investigated in this study. One mixture consisted of a plain that is commonly used in projects. The other five mixtures were made by modifying the control mixture with the addition of fibers to it. The materials used for this project was obtained from sources that are Reliable sources to the construction Industry.

All concrete mixtures developed for this project were made with the consideration of I.S. 10262(2009).
In order to achieve the strength in concrete, the mixtures had high cement content, low water-cement ratio, fibers and superplasticizer.

### 3.1 Material

The raw materials used in this project were obtained from sources and suppliers that are approved by various Bodies in India. Portland cement from a single source was used to eliminate discrepancies and variations in material properties. The fine and coarse aggregates were also obtained from a single supplier and obtained in one batch. The chemical admixtures were obtained from two suppliers. Only water – reducing admixture was used in preparing the specimens. The fibers were obtained from a verified source. Tables 2 and 3 list the materials and fibers used in this project along with their suppliers.

**Table -1:** List of Materials and their suppliers

| | Material | Supplier |
|---|---|---|
| Cement | OPC – 43 Grade | Vasavadutta – Birla Shakti Cement Vasavadutta |
| Coarse Aggregate | 10 mm, 20 mm | Kakade Stone Crusher, Pune |
| Fine Aggregate | Crushed Sand | Kakade Stone Crusher, Pune |
| Admixture-Superplasticizer | MasterRheobuild 1125 | BASF |
| Water | Tube Well | - |

**Table -2:** List of Fibers and their suppliers

| | Material | Supplier |
|---|---|---|
| Fiber | Recron 3S Polypropylene 18mm | Reliance industries |
| Fiber | Coconut 18 mm | Locally Available |

**3.2 Mixture Proportions**

Specimens were prepared with Ordinary Portland cement manufactured by Vasavadutta Cement - a unit of Birla Shakti Cement in Sedam, Gulbarga, Karnataka. Crushed sand with a fineness modulus of 2.48 and 10mm, 20mm stones were used for the fine and coarse aggregates, respectively. All mixtures were proportioned to comply with the I.S code provisions for minimum required workability and strength. It should be noted that no attempt was made to optimize the mixture containing fibers in order to isolate the fiber's effect on concrete properties. Water-reducing admixtures were used to achieve the desired level of workability. A Single dose of fibers were used, while it was further varied in proportions in this project. A dosage of 0.33% by weight of cement was used for mixtures. Mixture M0 was a control mixture with no added fiber content. The general mixture proportion is given in Table 3.

**Table -3:** Mixture Proportions (all units are in kg, unless noted)

| | Material | Quantity |
|---|---|---|
| **Cement** | OPC 43 Grade | 419 |
| **Coarse Aggregate** | 10 MM | 355 |
| | 20 MM | 827 |
| **Fine Aggregate** | Crushed Sand | 794 |
| **Water** | Tube Well | 167.5 |
| **Admixture** | Superplasticizer | 3.3 |

Aggregates weight is given in SSD condition

As mentioned earlier, the mixture M0 was the control mixture using plain concrete with no fiber added to it. Mixtures M1-M5 had polypropylene fibers and coconut fiber in proportions such as the proportion of polypropylene fiber decreasing starting with 100% in M1 and 0% in M 5 while coconut fiber starting with 0 % in B1 and 100% in B5. Table 4 summarizes the fiber type and Percentage used in each mixture.

**Table -4:** Fiber type and Percentage used in each mixture

| Mix | Proportion of fibers in total fiber content (0.33%) by weight of Cement | |
|---|---|---|
| | Polypropylene | Coconut |
| M1 | 100 | 0 |
| M2 | 75 | 25 |
| M3 | 50 | 50 |
| M4 | 25 | 75 |
| M5 | 0 | 100 |

## 3.3 Specimens Fabrication

A set of three specimens per testing sequence was prepared for all tests and mixtures. A 150 x 150 x 150 mm specimen Cubical in shape complying with I.S Code 10086:1982 was used for measuring the compressive strength. A 500 x 100 x 100 mm specimen Rectangular in shape complying with I.S Code 10086:1982 was used for measuring the flexural strength.

## 3.4 Curing and Storage

The test specimen were stored in a place, free from vibration, in moist air (covered with jute bags) at a temperature of 27° ± 2°C for 24 hours ± l hour from the time of addition of water to the dry ingredients. After this period, the specimens were marked and removed from the moulds and immediately submerged in clean, fresh water and kept there until taken out just prior to test.

**3.5 Material Properties**

**3.5.1 Cement**

43-Grade Ordinary Portland cement manufactured by Vasavadutta Cement - a unit of Birla Shakti Cement in Sedam, Gulbarga, Karnataka conforming to I.S 8112:2013 was used for the project.

The properties of cement are as tabulated below:

**Table -5:** Properties of cement

| Sr. No. | Property | Result | Limit as per Standards |
|---|---|---|---|
| 1. | Fineness | 1.64% | <10 |
| 2. | Standard Consistency | 32% | |
| 3. | Initial Setting Time | 42 | <30 min |
| 4. | Final Setting Time | 320 | <600 min |
| 5. | Specific gravity | 3.11 | |
| 6. | Compressive Strength | Mpa | Mpa ($N/mm^2$) |

| | | | |
|---|---|---|---|
| | 3- days | 23.41 | 23 |
| | 7- days | 34.84 | 33 |
| | 28- days | 45.67 | 43 |

### 3.5.2 Aggregate

The properties of all aggregates are tabulated below:

**Table -6:** Properties of Aggregates

| Sr. No. | Property | Crushed Sand | 10 MM | 20 MM |
|---|---|---|---|---|
| 1. | Specific Gravity | 2.72 | 2.93 | 2.91 |
| 2. | Water Absorption | 0.95 | 0.95 | 0.93 |

### 3.5.3 Fibers

The properties of fiber are tabulated below:

**Table -7:** Properties of Fibers

| Sr. No. | Property | Unit | Value | |
|---|---|---|---|---|
| | | | Polypropylene | Coconut |
| 1. | Diameter | Micron | 40 | 300 |
| 2. | Length | MM | 18 | 18 |
| 3. | Aspect Ratio (l/d) | - | 450 | 60 |
| 4. | Melting Point | °C | 240 | 150 |
| 5. | Moisture | % | <1 | <5 |
| 6. | Specific Gravity | Cc/gm | 1.34 | 1.43 |

## 3.6 Laboratory Tests

Several laboratory tests were conducted to determine the mechanical properties and cracking performance, which are discussed in this section. The compressive strength and flexural strength were used to determine the mechanical properties.

### 3.6.1 Compressive Test

The compressive strength test for the different mixtures was carried out in accordance with I.S. 516:1959. A 150 X 1510 X 150 mm Cubical specimen was used for this test. The test was carried out at three ages, specifically at 7-days, 14-days, 28-days. Three specimens were used for each test and the average value was calculated from the test results. The specimens were cured in a water bath until they were tested. A 200 Tonnes compression machine with a uniform loading of 140 kg/sq. cm/min conforming to I.S. 14858:2000 was used for testing the specimens.

### 3.6.2 Modulus of Rupture (Flexural Test)

The Flexural Test for the Beam specimens was carried out in accordance with I.S. 516:1959. One- point loading method was used, where the setup was made on the universal testing machine. Universal Testing Machine having capacity of 60 Tonnes with Micro Data Acquisition System was used. The test was carried out for two ages 7 and 28 Days.

## 4. Mix Design

The mix design is made in conformance to I.S. 10262:2009. The proportions of fiber being added in concrete are tabulated in table -4. As per the design a primary mix of plain concrete was prepared. The rest Five mixes included the proportion of fiber at a rate of (0.33% by weight of cement) such as polypropylene (100%-0%) in decreasing manner and coconut in the reverse one (0-100%).

The mix proportions are tabulated below:

**Table -8:** Mix proportion of FRC

| Sr. No. | Contents | Qty, Kg/m$^3$ | Ratio by Weight |
|---|---|---|---|
| 1. | Cement | 419 | 1 |
| 2. | Fine Aggregate | 794 | 1.89 |
| 3. | Coarse Aggregate II | 827 | 1.97 |
| 4. | Coarse Aggregate I | 355 | 0.85 |
| 5. | Water | 167.5 | 0.40 |
| 6. | Admixture | 3.3 | 0.007 |
| 7. | Fiber | 1.38 | 0.003 |
| | Density of Fresh Concrete | 2567.18 | Kg/m$^3$ |

**Table -9:** Fiber Proportions

| Sr. No. | Contents | Fiber | |
|---|---|---|---|
| | | Polypropylene | Coconut |
| 1. | B0 | 0 | 0 |

| | | | |
|---|---|---|---|
| 2. | B1 | 1.38 | 0 |
| 3. | B2 | 1.03 | 0.35 |
| 4. | B3 | 0.69 | 0.69 |
| 5. | B4 | 0.35 | 1.03 |
| 6. | B5 | 0 | 1.38 |

All units are in Kg

## 5. Results and Discussions

In this section the results of the laboratory experiments detailed in Chapter 3 are discussed. Plastic properties, mechanical properties and cracking performance as well as any observations made during mixing are discussed here. Balling of fiber is first discussed in this as it is a major issue with handling fibers which is later followed by a discussion on the plastic properties. The mechanical properties and cracking performance are discussed next.

### 5.1 Mixing Observation

The first task carried out was to determine the best method in distributing the fibers into concrete. The mixing method was crucial in determining a uniform fiber distribution and in preventing the formation of fiber clumps and balls. Preliminary investigations were made using trial batches to select the best mixing technique for making FRC. The main difference in the mixing techniques was in the mechanism in which the fiber was added. Fibers were added in two different techniques and were tested to compare the distribution of fibers and their susceptibility to fiber balling. The first technique, T01, was mixed by adding the fibers in dry state along with the coarse and fine aggregates prior to the addition of water. In the second technique, T02, the fibers were added in the wet state after the addition of water. The fibers were added into the mixer in small bowls to simulate the field condition. Visual inspections of the concrete in plastic state were carried out to check for instances of fiber balling. The hardened specimens from both techniques were cut and visually inspected for uniformity of the fiber distribution along the concrete matrix. The 7 days compressive strength specimen was also tested to compare and check for the presence of defects due to improper mixing and fiber balling.

Based on the visual inspection and compressive strength results, both techniques provided good distribution of fiber in concrete. However, the second technique provided better matrix consistency for Coconut fiber where balling was encountered. The fibers get wet easily when water is added to the dried mixture when using the mixing procedure developed for the first technique. As the coconut fiber becomes wet, it tends to clamp together forming fiber balls. These fiber balls produced corner pockets and prevented proper consolidation. Regardless of the technique used in mixing, the fibers would stick and accumulate along the mixing blades of the mixer, which means not all added fibers are incorporated into the mixture.

### 5.1 Mechanical Properties

The mechanical properties that were investigated in this study were compressive strength and flexural strength.

#### 5.1.1 Compressive Strength Test

The results of the compressive strength tests at three different specimen ages (7days, 14 days, 28 days) are listed and depicted in Table 10 and Chart 1 respectively. As can be seen from the test results, in general FRC had higher compressive strength comparing to ordinary concrete. One noticeable difference was the compressive strength of Coconut FRC was in general higher (about 30-40% more) in comparison to ordinary concrete (control mixture). This could be attributed to the fiber confining the concrete at early-age. As shown in Figure 2, the specimens with fiber showed higher shatter resistance as compared to the control specimens. Unlike the fiber reinforced concrete, the plain concrete specimens were shattered, while the former stayed in one piece after been subjected to ultimate load. All the mixes had an initial setting time of approximately 5 hours. Another observation that was made was the mixture containing Polypropylene fiber (25%) and coconut fiber (75%) had a strength reduction at all ages, which could be attributed to fiber balling encountered for these mixtures that prevented proper consolidation and fiber distribution.

**Table -10:** Compressive Strength of Cubes

| Sr. No. | Sample No. | Compressive Strength | | |
|---|---|---|---|---|
| | | 7 Days | 14 Days | 28 Days |
| 1. | B0 | 20 | 24.2 | 31.25 |
| 2. | B1 | 22.1 | 30.5 | 39.26 |
| 3. | B2 | 22.2 | 27.5 | 36.1 |
| 4. | B3 | 23.4 | 30.1 | 36.90 |
| 5. | B4 | 23.5 | 27.2 | 36.45 |
| 6. | B5 | 24.7 | 31.2 | 44.45 |

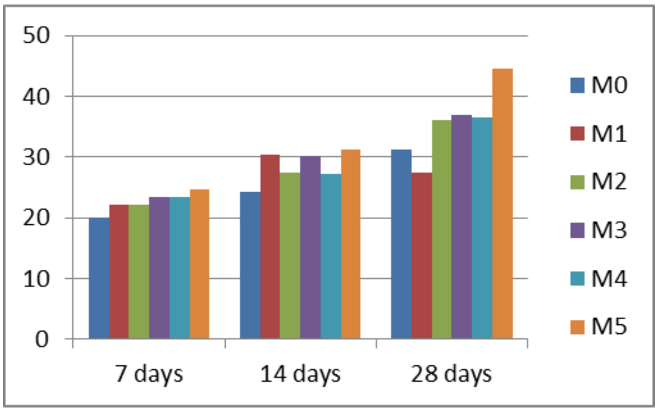


**Chart -1**: Compressive strength of the mixes (Age of specimens on X-axis and Compressive Strength in Mpa on Y-axis)

**Figure 2:** Concrete cube casted with FRC shows higher shatter resistance

### 5.1.2 Modulus of Rupture

Flexural strength of concrete means the tensile strength which it can take. The behavior of the FRC was expected to be superior as compared to ordinary concrete. However, the fiber volume fraction chosen showed a small increase. It is also observed that fibers with higher stiffness had the highest modulus of rupture. The results of the modulus of rupture test are given and depicted in Table 4.4 and Figure 4.6, respectively.

**Table -11:** Flexural Strength of Beams

| Sr. No. | Sample No. | Flexural Strength | |
|---|---|---|---|
| | | 7 Days | 28 Days |
| 1. | B0 | 3.86 | 4.24 |
| 2. | B1 | 3.82 | 4.97 |
| 3. | B2 | 3.93 | 5.06 |
| 4. | B3 | 4.06 | 4.84 |
| 5. | B4 | 4.05 | 5.05 |
| 6. | B5 | 4.27 | 5.25 |

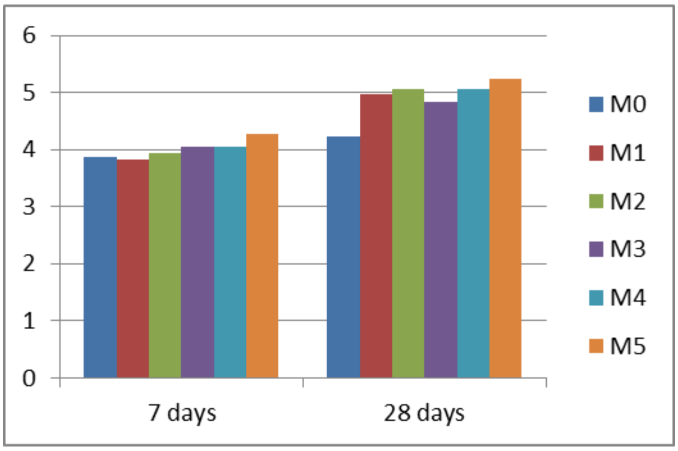


**Chart -2**: Flexural strength of the mixes (Age of specimens on X-axis and Flexural Strength in Mpa on Y-axis)

As can be seen from the above stated test results, almost all mixtures had low modulus of rupture. This is typical of an ordinary concrete which had low flexural strength. By introducing a fiber in to the mixture, the modulus of rupture was increased only to a small degree. To attain significant improvements the fiber volume fraction should be much higher. In addition, the tensile and bond strengths of the fiber should be higher. In this test fibers with higher tensile strength performed better than those with lower tensile strengths. Coconut and polypropylene fibers increased the modulus of rupture by 21% and 31%, respectively. Although the percentages showed good improvements, in reality it is not as high as the percentages. Two modes of failure were identified in this test. For fibers with lower tensile strength, the mode was tensile failure in concrete immediately followed by tensile failure of the fibers. While fibers with higher tensile strength the mode was tensile failure of concrete followed by a delayed pull out of the fibers. Unlike in the first mode of failure discussed above, in the second mode of failure the specimen stayed intact after the onset of tensile cracking. Figures 3 and 4 show pull out of fibers and failure modes. Another factor was the fiber length. The longer the fiber, the better the bond strength. Ideally the fiber which are long in length and dia is greater will have higher tensile and bond strength will improve the tensile strength of concrete.

**Figure 3:** Pull out of coconut fibers. The holes indicate pull out locations

**Figure 4:** Mode of Failure (centre-point loading)

## 6. CONCLUSIONS

Six mixes were tested to compare their potential use in helping concrete improve its strength. In general, adding fibers to a concrete mixture was found to be beneficial in increasing the age at cracking and reducing the crack width. As the diameter of Polypropylene fiber is very minute it dint add up for strength in the mixes while coconut fiber was the main part of interest in this. It helped concrete achieve better compressive as well as flexural strength, it holds up the concrete better against crushing/shattering. It being a relatively cheap option to other fibers has its drawback being a natural fiber. It was evident that stiff fibers (higher flexural strength) like polypropylene fibers tend to provide good flexural strength, but are relatively poor in restrained shrinkage cracking. Coconut fibers can be used to restrain early age cracking, however, care must be taken when mixing as fiber balling was encountered. These fibers tend to get wet and once wet form fiber balls and prevent proper consolidation of the concrete especially around corners. Some other conclusion includes:

1. It can also be concluded that there will not be significant influence on workability and unit weight due to low volume fraction fiber addition to concrete.

2. Addition of fibers to concrete can increase the early age compressive strength by up to 48%. Furthermore the age at cracking can be more than doubled by just adding 0.3% volume of polypropylene fibers. Other fibers can also be used for intermediary effects. Coconut fibers are found to provide residual strength, however they are also prone to deterioration due to corrosion.

3. For coconut fiber as it can be susceptible to corrosion if water seeps through it, it was not seen during the 28 days test after the specimens were removed from water that coconut fiber has been deteriorated or corroded. But from safety point of view it must be used for less important works.

4. It is also seen that at this percentage of fiber (0.33%) the micro-structure cracking or shrinkage cracks are not seen/ rare as compared to conventional.

5. With a holistic approach to the use of fiber reinforced concrete it has an advantage of controlling early age cracking and increasing early age strength. However the choice of fiber should be given due consideration as different types of fibers perform differently. A fiber with high tensile strength, higher pull out strength and lower flexural strength will be the best suited one to control early age shrinkage cracking. The choice of fiber type and volume fraction would depend on the desired effect or property. As far as controlling early age shrinkage cracking is concerned a mix with a combined effect of higher early age compressive strength, longer age at cracking and smallest crack width would be best suited.

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