



Experimental Study on Strength and Durability Characteristics of Polyester and Jute Fiber Concrete.

¹Jessly Rajan, ²Nitin Soni, ³Janmesh Bhoir

¹Assistant Professor, ²Lecturer, ³Student

¹Department of Civil Engineering,

¹Datta Meghe College of Engineering, Airoli (navi Mumbai), Maharashtra, India.

Abstract : Concrete undoubtedly is the most important material in the field of construction. The purpose of this research is to study the strength and durability properties of the polyester and jute fiber concrete. Hence an experimental work was conducted to optimize the volume fraction of concrete based on its ease to be cast and mould using different workability tests. This paper also concentrates in understanding the effect of the fibers on the shrinkage properties, post peak response and energy dissipation of concrete, which otherwise fails suddenly due to its brittle nature on reaching maximum load. It was observed that the compressive strength and split tensile strength of the concrete specimen had increased by 24.6% and 88.7% on the addition of 0.5% volume fraction of polyester fiber. Similarly, there was significant increase in the compressive strength and split tensile strength of the concrete specimen by 19.4% and 95.4% on the addition of 0.1% volume fraction of jute fiber. Later the cubes were placed in artificial adverse environmental conditions where the change in the appearance and strength of the concrete was determined. It was observed that there was a notable change in the colour of the concrete under acidic and seawater condition. Based on the compressive strength results, it was concluded that there was a considerable reduction of strength by 25.4% and 30.2% in acidic condition and 8.6% and 15.7% in seawater condition for 0.3% and 0.5% volume fraction of polyester fiber in concrete respectively. Similarly, the compressive strength of the jute fibers had decreased by 13.1% and 4.9% in the acidic condition and 6.8% and 1.2% in the saltwater condition for 0.1% and 0.3% volume fraction. A clear idea about the transport mechanism of the deleterious materials in the concrete was obtained when the adverse conditioned cube strengths were compared to the cubes cured under ambient conditions.

IndexTerms - Carbonation tests, durability tests, fiber concrete, jute fibers, mechanical properties, post peak response.

I. INTRODUCTION

Concrete is the most important material in the evergreen field of construction and infrastructure. But concrete has its own limitations, like very low tensile strength and its tendency to fail in a brittle nature. Short fibers in the form of secondary reinforcements have been used since olden times to improve the quality of concrete. Historically, natural fibers such as horsehair and straw were used in mortar and in mud bricks as reinforcement. Asbestos was the material that was commonly used in the early 1900's. However, in the late 1900s, the synthetic fibers like polyester, polypropylene etc came into existence. Researches were done on the synthetic fibers which lead to the invention of micro and macro fibers. Fiber concrete is one such field that progresses on the daily basis. India is well acquainted and researched with fiber reinforced concrete since last 15 years. Hence it can be concluded that the popularity of fiber concrete is increasing since last two decades. Probably every day new fibers are being tested in concrete to enhance the properties of plain concrete in the tensile strength and shrinkage aspect. Strength and durability are often regarded as the most important criteria in concrete structural designs. These criteria especially apply for marine structures, which are exposed to hazardous environments. The durability of concrete may refer to its ability to resist quality degradation when exposed to environments that cause deleterious effects to the concrete. These attacks include chloride attack, acid rain attack, rapid expansion and shrinkage at the splash zone, salt crystallization, abrasions and erosions by the waves, carbonation etc.

Among the many synthetic fibers put in concrete, polyester fiber is considered as one among the best synthetic fibers. It is a monofilament put in a very low fraction. Similarly, polymer modified jute fibers are also used as reinforcing element in cement concrete in which polymer will chemically bridge jute in one side and cement on the other side. Polymer modified jute fiber 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.

Hence this research is to find out the workability, strength and durability properties of concrete on the addition of the polyester and jute fibers in the concrete.

II. LITERATURE REVIEW

2.1 Necessity and advantages of polyester and jute fibers in concrete

The main reason of using fibers in concrete is to enhance its ability to self-repair itself during cracking before and after loading.

This unique and sensitive quality of concrete has lead fiber concrete gain its momentum. Certain cracks are so thin that they are called as the hairline cracks and are invisible. Hence the invention of fiber concrete gained its momentum. Fiber has the unique quality to arrest cracks at the initial stage. When compared to the conventional concrete, the fibers do not allow the micro cracks to develop into much wider cracks thereby reducing the permeability of concrete. In a research paper by Elie Awwad, Mounir Mabsout, Bilal Hamad and Helmi Khatib (2010) [1] stated that to increase the mortar & concrete behavior and sustainability, the natural fiber must be easily dispersed in the mixture. Fibers are classified as natural fibers, synthetic fibers, steel fiber etc. In the report submitted by cement & concrete institute (2010) [2] one of the most prominently used synthetic fiber is Polyester fibers. It is fiber which is monofilament in nature and belong to the thermoplastic polyester group. Unlike the natural fibers, the polyester fibers are hydrophobic at means they absorb negligible water from the concrete. According to the report submitted by the cement and concrete institute [2], polyester fibers are to be used at very low contents of volume fractions (from 0.1% upto 0.5% volume) in order to control plastic-shrinkage cracking in concrete. They are also used to improve the tensile strain capacity and tensile strength of the concrete when it is in the plastic static by arresting and binding the micro cracking that occurs in the concrete which further reduces the permeability of concrete. In the same paper, it was also mentioned that Jute is the most commonly used natural fiber in concrete.

2.2 Volume fractions in concrete and fiber orientation

The fibers types and its properties play an important role in the volume fraction criteria. They can be put in high, moderate or low volume fraction. This affects many parameters in the concrete like its strength, workability etc. It is mentioned in a paper published by the Cement & Concrete Association of New Zealand (2009) [3] that it is mandatory to add fibers in low volume fraction (less than 1% of the volume of the concrete), moderate volume fraction (1% to 2% of the volume of the concrete) and high-volume fraction (more than 2% of the volume of the concrete). However, the selection of the fiber volume fraction depends on its mechanical properties and its modulus of elasticity. For example, for the concrete that need to be placed in a highly important place or under severe climatic working condition, then high volume fraction of fibers is to be used like the steel or carbon. The next parameter that helps in the production of a good fiber reinforced concrete is dispersion. Dispersion of the fibers should be good so that they are well separated from each other. It should be well distributed such that each fiber is surrounded by the matrix. Micro cracks can be arrested only when the fibers are well distributed reaching all the corners of the concrete. The property of fiber bond and its cut length play an important role in the reduction of cracks property. However, none of these theories have been conclusive or substantial. Now the fibers can be placed in the concrete in many ways like they could be randomly thrown in concrete mix or laid symmetrically. Material property of isotropy and anisotropy of the fibers is a very strong point that could help in the orientation of the fibers in the direction of the loading axis. But it is impossible to lay the synthetic fibers in the same loading axis due its ability to ball. Hence, they are preferably randomly dispersed or laid as sheets in the concrete. A very important property in fiber concrete is to understand the concept of fiber aspect ratio, which is the ratio of length to the diameter of the fiber. It is advised to keep the aspect ratio of the fibers in between 50 to 150.

2.3 Different strength tests on fiber reinforced concrete

Civil engineering is a vast field of engineering. One such field is the highway engineering. The major application of Polyester Fiber Reinforced mortar is in the form of pavements found to be in the construction of the roads and highways. Road constructions prefer polyester fiber concrete due to its low shrinkage property. Many researchers have experimented to evaluate the various strength properties of plain cement mortar, with and without the addition of polyester fiber. The major findings were focused in the split tensile strength since concrete is weak in tension hence it was observed that polyester fibers would increase the tensile strength of mortar. It was noticed that the Polyester Fiber Reinforced mortar not only improved the split tensile strength but also the other strength parameters when compared to plain cement mortar. Damyanti and Modhera (2013) [4] evaluated the strength tests on various specimens containing fibers of different volume fractions 0.0, 0.3, 0.4, 0.5, 0.6, 0.8 and 1.0 % were. They aimed at optimizing the volume fraction of fibers that helped in the improvement the compressive strength as well as split tensile strength of the polyester fiber cement mortar. It was observed that the Compressive strength of cement matrix mortar improved to 17.68 % after 7 days and Split tensile strength increased by 32.58 % at 7 days & 70.37 % at 28 days for 0.5% volume fraction of fiber. Nilson (2011) cut fibers of 10-30mm and used them while casting, and later he observed high tensile strength in the beams.

2.4 Different durability tests on fiber reinforced concrete

The knowledge of the mechanical properties of a newly invented concrete is the need of the hour. But along with the mechanical properties it is very essential to know the durability of the concrete to have a clear idea about its sustainability against climatic conditions. Reynolds Roque, Namho Kim (2009) [5] explained that short fibers are added in the concrete to increase the strain characteristics and toughness of the concrete. But it was noticed that fiber reinforced concrete placed in swamps, marine surroundings had effects on its performance. Carbonation was also observed in the concrete. It was explained as the dissolution of CO₂ due to the fluid in the pore and its reaction with calcium from calcium hydroxide and calcium silicate hydrate to form a product called calcite (CaCO₃). It is assumed that carbonation affects the corrosion and the shrinkage of the concrete. It was also explained in the paper that cracking can be induced in the concrete either by mechanical or chemical means which can be called as the deleterious materials in the concrete. These conditions deteriorate the concrete from within and outside. Hence research was done in form of acidic test, alkaline test, freezing- thawing test, tidal action test and saltwater test on fibers and concrete. However, Karthik Obla, Colin Lobo and Lionel Lemay (2005) [6] explained that the freezing – thawing test, cyclic alkalinity test and the tidal action tests need to be observed for at least six months which could go up to 21 months, hence it is not covered in this part of research. In this paper, the fiber reinforced concretes (polypropylene and steel) were placed in acidic conditions using acetic acid, where the pH of the water was brought down to 4 to 5 to maintain the swamp conditions. Similarly, the concrete was also placed in marine condition that is in saltwater water for 14 days alternate cycles. For most of these attacks, the results of the attacking mechanism are frequently related to the initiation of cracks due to the volume changing or expansive nature of the reactions products. However, some mechanisms involved in the deterioration of concrete especially fiber concrete is not known completely. Hence there is an ardent need for techniques and tests to check the durability of concrete under adverse environmental conditions. The susceptibility of the fibers in these adverse conditions can give an overall idea about the durability of the fibers under sudden or

prolonged chemical attack.

2.5 Post peak response and energy dissipation in concrete

Concrete either normal or fiber reinforced are tested for strength parameters like compressive strength or tensile strength where the observations obtained from the stress versus strain curves are considered important in analyzing the behavior of concrete. The conventional concrete is observed to have a sudden drop in the stress versus strain graph after reaching the maximum or the ultimate load. Whereas the fibers have been found to improve the 'ductility' of the material or in broader terms have increased the energy absorption capacity of concrete. There is considerable change in the post peak response of fiber concrete as compared to normal concrete. This means that if an attempt is made to optimize the volume fraction of fiber in concrete for strength characteristics alone then it can lead to a much tougher and ductile concrete. Hasan, Afroz and Mahmud (2011) [7] In their experimental work observed that the peak strain values of concrete with polypropylene fibers of volume fractions ranging between 0.2 to 0.5% increased considerably by 60% which proved that the fibers even though did not increase the ultimate stress of the concrete but had the ability to increase ductility of concrete or the occurring creep and to strew stresses thereby slowing down the crack proliferation process. There is a significant drop in the strength when the jute fibers are used in the volume fractions more than 0.3% hence the research in this paper is restricted upto only 0.3% for the jute fibers.

III. EXPERIMENTAL SETUP

The experimental programme in this research was divided into two parts: workability test, mechanical properties of concrete, post peak response or ultimate strain at failure, plastic shrinkage in concrete and durability tests on concrete. This research was done to study effects on the strength, shrinkage and durability properties of concrete on the addition of polyester fibers.

3.1 Treatment of the jute fibers

Jute shows hydrophilic character which leads to the depletion of water from the wet concrete mix, as it might decay in due course of time as a result of microbial attack. So, 0.5 L NaOH solution with fiber to liquor ratio 1:30 is made and the jute fibers are immersed for 1hour. These fibers were then washed several times to remove excess alkali then air dried at room temperature.

3.2 Casting of the cubes

The main constituent of the research carried out was polyester fibers. The sample of fibers used in this research is as shown in Fig. 1.



Fig 1. Polyester and Jute fiber sample

The properties of Polyester fibers are given in Table 1 [9].

Table – 1: Properties of Polyester Fibers

Diameter (micron)	Cut length (mm)	Specific Gravity Kg/m ³	Tensile Strength (GPa)	Elastic Modulus (GPa)
120 - 130	12	1.4	4 - 6	8.3

The properties of the jute fibers are given in Table 2 [10].

Table – 2: Properties of Jute Fibers

Diameter (mm)	Cut length (mm)	Specific Gravity Kg/m ³	Tensile Strength (GPa)	Elastic Modulus (GPa)
0.1 - 0.2	30	1030	2.5 – 3.5	26 - 32

The polyester fiber introduced in the concrete had an aspect ratio of 92 which is the ratio of fiber cut length to its diameter. Ordinary Portland Cement (OPC) of good quality was used as a binder. During the entire study, constant water – cement ratio of 0.5 and 0.45 was maintained. The concrete was mixed in the proportion of 1:2.3:2.5:0.5 for strength tests and 1:2.1:2.3:0.45 for durability tests with the target grade of concrete as M25. Table 3 and 4 gives the quantities of the materials used in the fiber reinforced concrete with M25 grade of concrete. However, table 5 gives us the volume fractions used for the strength and durability tests.

Table – 3: Quantities of materials in mix design for the strength tests

Cement kg/m ³	Fine Aggregate kg/m ³	Coarse Aggregate kg/m ³	Water kg/m ³
380	897	966	190

Table – 4: Quantities of materials in mix design for the durability tests

Cement kg/m ³	Fine Aggregate kg/m ³	Coarse Aggregate kg/m ³	Water kg/m ³
422	897	966	190

Table - 5: Quantities of fiber in mix design for the strength and durability tests

Fiber Name	Strength Tests Volume Fraction (%)				Durability Tests Volume Fraction (%)	
	0.1	0.3	0.5	-	0.3	0.5
Polyester Fiber	0.1	0.3	0.5	-	0.3	0.5
Jute Fiber	0.1	0.3	-	0.1	0.3	-

Sixteen cubes were casted of the size 100mm x100mm x100 mm and sixteen cylinders of diameter 100mm and height 200mm with three different volume fractions of polyester fibers in concrete as shown in the Fig. 2.



Fig 2. Fiber reinforced casted cubes

Twenty-Seven cubes were casted of the size 100mm x100mm x100 mm with two different volume fractions of polyester fibers in concrete as shown in the Fig. 3.



Fig 3. Fiber reinforced casted cubes

3.3 Workability test on concrete

Slump test is considered as one of the most convenient test in checking the workability of concrete. This test is not suitable in case of stiff or very wet concrete. This test is also called as the control test to check the consistency of concrete. The apparatus used in this test is a metallic frustum of a cone having internal top diameter as 100mm, bottom diameter as 200mm and height as 300mm. The mixed concrete both normal and fiber reinforced was filled in the slump cone in four layers and tamped 25 times using a tamping rod. The mould is then lifted and it is noticed that the concrete subsides giving the slump of the concrete which the difference in the height between the highest point in the mould and subsided concrete. The second test that was conducted was the Vee Bee consistometer that helped in the consistency of the concrete. The Vee Bee consistometer is performed by filling the slump cone and the placing the slump cone in the cylindrical pot. The vibrator is then switched on and the time taken for the concrete cone to completely assume a cylindrical shape is measured. Later the V- box test was also conducted but the fibers were obstructed through the small opening. Hence it is difficult to conduct the V box test on the fiber concrete. It is very important to note that the workability tests were done on the polyester and jute fibers for different volume fractions. The image of slump cone and vee bee consistometer used for the test is given below in the Fig.4 and Fig.5.



Fig 4. Slump cone mould



Fig 5. Vee Bee consistometer

3.4 Compressive and split tensile strength of concrete

The tests were performed with the help of a universal testing machine which has a loading speed of 10 mm per. The compressive strength of the concrete cubes (100mm x100mm x100 mm) was observed after 28 days. The formula used to calculate compressive strength F_{cu} (Mpa) is given below.

$$F_{cu} = P / ab \dots\dots\dots (1)$$

Where P is the maximum compressive load in (N)
a and b are the dimensions of the cube in (mm).

A split tensile test was performed after 28days. The prepared cylinders (diameter 100mm and length 200mm) were tested and a failure load or the ultimate load P (N) was measured.

The formula used to calculate the split tensile strength of concrete is given below.

$$F_{ct} = P / \pi LD \dots\dots\dots (2)$$

Where F_{ct} was the maximum tensile splitting strength (MPa),
L and D are the length and diameter of the cube (mm).

3.5 Artificial adverse environmental conditions

Durability is considered as a very important factor in the assessment of the quality of the concrete. In this test, the optimized volume fraction depending on its workability is subjected to various adverse climatic conditions like the swamp condition, carbonation test and the seawater condition for 30 days. The adverse condition of swamp and acid rain are artificially simulated by reducing the pH of water to 4, adding acetic acid. The concrete cubes were also immersed in sea water for 30 days. Figure 6 below shows the setup of the adverse environmental conditions on the polyester fiber concrete. Later visual inspection and destructive tests were done on the cubes to understand the transport mechanism of deleterious material into the control and fiber concrete.



Fig 6. Adverse environmental condition setup

3.6 Carbonation test on concrete

This test is carried out to determine the depth of concrete affected due to combined attract of atmospheric carbon dioxide and moisture causing a reduction in level of alkalinity of concrete. Carbonation test is the test that is carried out to measure the depth of concrete that has been reacted by the combination of atmospheric carbon dioxide and water which thereby reducing the level of alkalinity in the concrete. The carbonation test was conducted on the chips of the fiber concrete by spraying phenolphthalein solution on them. The Fig. 7 below shows the phenolphthalein used in this test.



Fig 7. Phenolphthalein

Phenolphthalein is a white or pale-yellow chemical used as an indicator it is dissolved in a suitable solvent such as isopropyl alcohol (isopropanol) in a 1% solution.

IV. RESULTS AND DISCUSSION

4.1 Workability test results

The standard slump cone test helped in understanding the consistency and workability of concrete that is the ease with which the concrete can be casted and tested due to addition of fiber which may hamper the flow ability of concrete. Table 6 shows the results obtained by the standard slump cone test on concrete.

Table – 6: Slump test result

Sr. No.	Volume fraction (%)	Slump (mm) Polyester	Slump (mm) Jute	Observation
1.	0% fibers	40	42	Slight shear
2.	0.1% fibers	35	24	Less shear
3.	0.3% fibers	20	8	True slump
4.	0.5% fibers	0	-	No slump

Further the Vee Bee consistometer also helped in concluding the optimum fiber content in terms of workability characteristics. Table 7 shows the results by the Vee Bee consistometer.

Table – 7: Vee Bee consistometer test result

Sr No.	w/c ratio with fiber content	Polyester - Vee Bee Time in (secs)	Jute - Vee Bee Time in (secs)
1.	0.45 with 0% fibers	15	14.86
2.	0.45 with 0.1% fibers	24	31.03
3.	0.45 with 0.3% fibers	31	42.5
4.	0.45 with 0.5% fibers	43.5	-

From the table it is evident that as the volume fraction of the fibers increase the ease to work with concrete decreases. Hence it can be concluded that if the fiber has to be added in a higher volume fraction, then it would be advisable to use a super plasticizer to increase the workability.

4.2 Strength test results for different volume fractions of polyester and jute fibers

It is very important to note that the water cement ratio kept for the strength tests is 0.5. The concrete cubes were loaded at a rate of 10mm/min until it completely

4.2.1 Compressive strength results for 28 days for polyester and jute fibers

The Table No.8 below shows the results obtained by the compressive strength test on control cubes and cubes with polyester fibers after 28 days.

Table 8. Compressive strength test result of 28 days

Sample Name	Volume fraction of polyester fibers	Compressive Strength (MPa) 28 days	Mean Strength (MPa)	Strength Increase (%)
C0	Control Specimen	24.9	24.93	-
		25.8		
		24.1		
C1	0.10%	26	25.93	4.01
		25.4		
		26.4		
C2	0.30%	28.2	27.77	11.36
		27.1		
		28		
C3	0.50%	29.6	29.10	16.71
		29		
		28.7		

The bar graph in Fig. 12 gives an illustrative idea of the compressive strength of concrete for control specimen and specimen containing 0.1%, 0.3% and 0.5% of fibers.

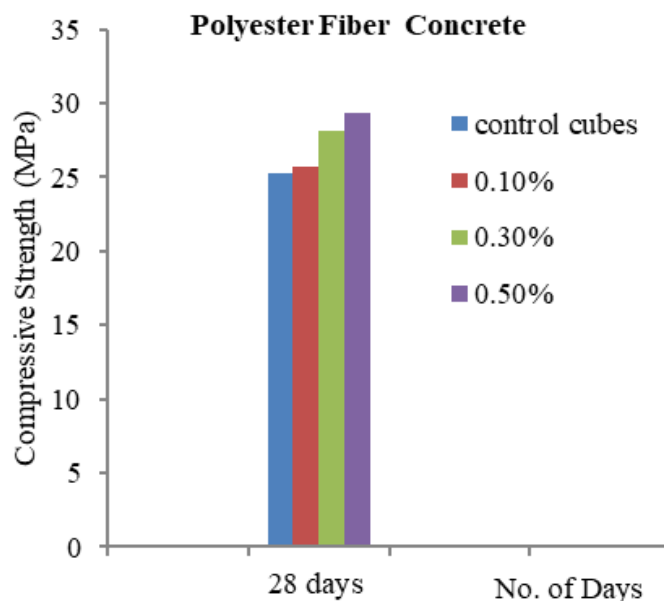


Fig 12. Bar graph of compressive strength test

From the bar graph it is evident after the 28 days of strength, the cube with maximum volume fraction of fiber 0.5% showed maximum compressive strength. Moreover it was also observed that there was no increase at all with 0.1% volume fraction of polyester fibers. Hence it is advisable to not use the 0.1% volume fraction of polyester in the concrete.

The Table No.9 below shows the results obtained by the compressive strength test on control cubes and cubes with fibers after 28 days.

Table 9. Compressive strength test result of 28 days

Volume fraction of jute fibers	Compressive Strength (MPa) 28 days	Mean Strength (MPa)	Strength Increase (%)
Control Specimen	23.2	25.3	-
	23.0		
0.1 %	29.0	27.6	9.1
	26.2		
0.3%	26.0	26.2	3.5
	26.4		

The bar graph in Fig. 13 gives an illustrative idea of the compressive strength of concrete for control specimen and specimen containing 0.1%, 0.3% and 0.5% of fibers.

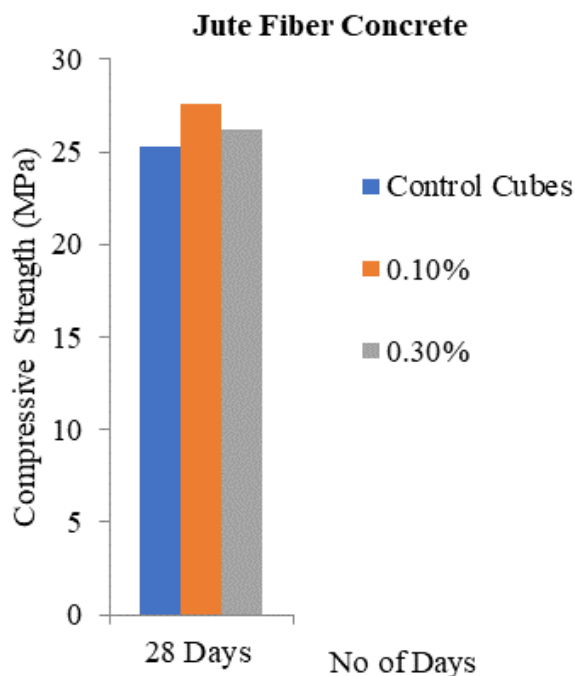


Fig 13. Bar graph of compressive strength test

From the bar graph it is evident after the 28 days of strength, the cube with maximum volume fraction of fiber 0.1% showed maximum compressive strength. Moreover it was also observed that there was a drop in the strength as the volume fraction increased to 0.3%.

4.2.2 Split tensile strength test results 28 days

The concrete cylinders were loaded at a rate of 10mm/min until it completely failed as shown in the Fig. 14.



Fig 14. Split tensile strength of cylinders

The Table No.10 below shows the results obtained by the Split tensile strength test on control cubes and cubes with fibers after 28 days.

Table 10. Split tensile strength test results of 28 days

Volume fraction	Tensile Strength (MPa) 28 days	Mean Strength (MPa)	Strength Increase (%)
Control Specimen	6.56	6.73	-
	6.91		

0.1 %	9.89	9.8	45.6
	9.71		
0.3%	11.36	10.9	62
	10.48		
0.5%	12.38	12.7	88.7
	13.02		

The bar graph in Fig. 15 gives an illustrative idea of the Split tensile strength of concrete for control specimen and specimen containing 0.1%, 0.3% and 0.5% of fibers.

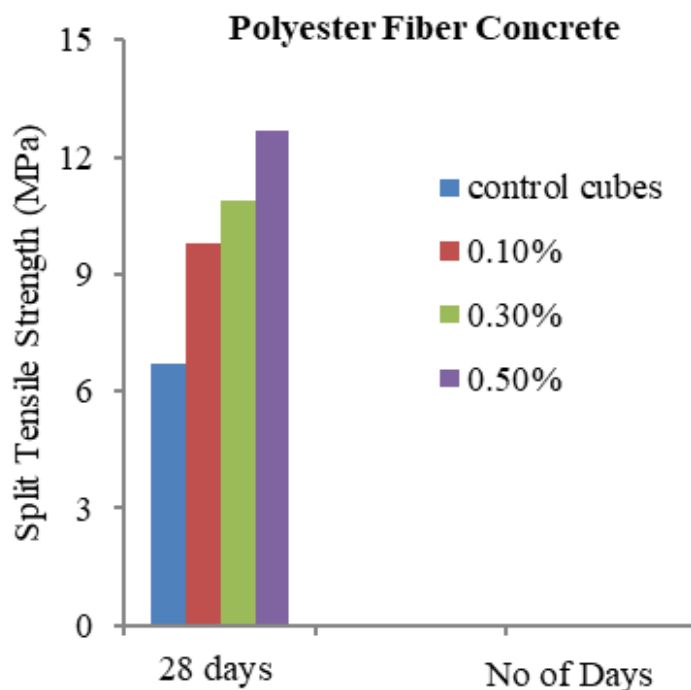


Fig15.Bar graph of compressive strength test

It is evident that after 28 days of strength, the cube with maximum volume fraction of fiber 0.5% showed maximum increase in the tensile strength.

The Table No.11 below shows the results obtained by the Split tensile strength test on control cubes and cubes with fibers after 28 days.

Table No 11. Split tensile strength of the jute fibers

Volume Fraction of Jute Fibers	Tensile strength (Mpa) 28 days	Mean Strength (Mpa)	Strength Increase (%)
Control Specimen	6.07	6.6	-
	7.12		
0.1%	13.2		90.9

		12.7	12.9	
0.3%		7.54	7.78	17.8
		8.02		

The bar graph in Fig. 16 gives an illustrative idea of the Split tensile strength of concrete for control specimen and specimen containing 0.1%, 0.3% and 0.5% of fibers.

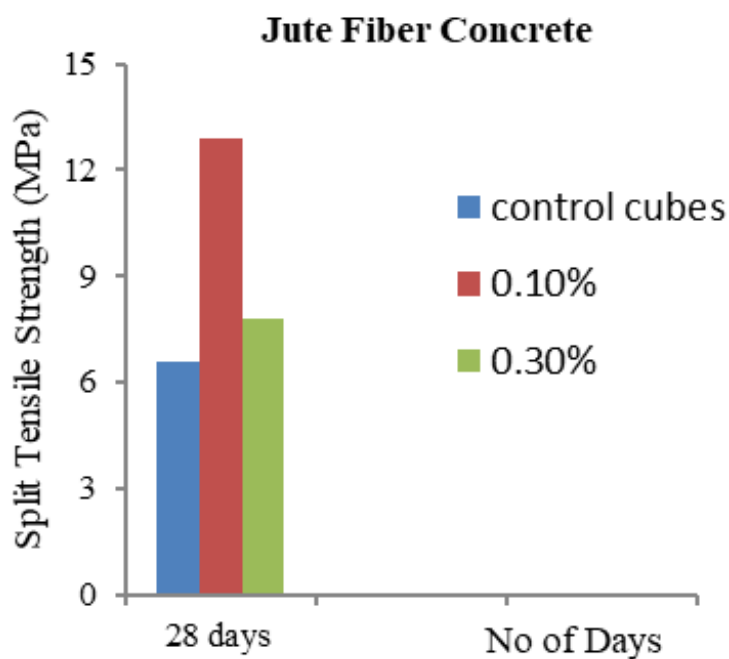


Fig 16.Bar graph of compressive strength test

From the bar graph it is evident after 28 days of strength, the cube with the volume fraction of fiber 0.1% showed maximum increase in the tensile strength.

4.3 Post Peak Response

In conventional testing machines, the specimen is tested under constant loading and small increments in the stress and strain are observed. However it is noticed that as soon as the concrete reaches its maximum value, even on small increment in the load the concrete fails abruptly and instantly. This shows the brittleness of concrete and hence the calculation of the post peak response becomes a necessity here. Thus the peak response can be obtained by observing the strain at the maximum load that is the highest point in the stress v/s strain graph and the ultimate strain or strain at failure. The extent of the graph beyond the strain at maximum load will help in understanding the ductility of concrete and also its contribution in reducing the initial phase cracks. Table No. 12 shows the results obtained after 28 days of curing of concrete regarding the extent of the strain beyond its peak point.

Table 12.Ultimate strain of the cubes at 28 days

Volume Fraction	Strain at maximum load	Ultimate strain
Control Specimen	6.48	6.89
0.1 %	5.69	7
0.3%	5.28	7
0.5%	4.31	8.1

From the results obtained from the table it is clear that the maximum post peak response was observed in cubes with 0.5% fiber volume fraction. However in the compressive strength test results, it was observed that the compressive strength of the cubes with 0.5% volume fraction of fibers increased gradually but its post peak response is observed to be maximum. This helps in interpreting that at the start of 7 days curing of concrete the fibers in concrete partially help in increasing the strength of concrete and partially in increasing the ductility of concrete. It also helps in understanding that fibers help in reducing the initial phase cracking in concrete. However it was observed from the graph that jute fibers do not help in the post peak response or the energy dissipation due its low tensile strength and energy absorption capacity.

V. ACKNOWLEDGMENT

It gives me immense pleasure to express my sincere thanks with deep sense of gratitude to Dr. P.A.Dode, Professor and Head, Civil Department, Datta Meghe College of Engineering, for his valuable guidance, encouragement and keen personal interest during the course of this project work. I am thankful to Mr. Nilesh Lende, Assistant Professor, for his constant encouragement and needful help throughout the completion of the project work.

REFERENCES

- [1] G. O. Young, "Synthetic structure of industrial plastics (Book style with paper title and editor)," in *Plastics*, 2nd ed. vol. 3, J. Peters, Ed. New York: McGraw-Hill, 1964, pp. 15–64.
- [2] W.-K. Chen, *Linear Networks and Systems* (Book style). Belmont, CA: Wadsworth, 1993, pp. 123–135.
- [3] H. Poor, *An Introduction to Signal Detection and Estimation*. New York: Springer-Verlag, 1985, ch. 4.
- [4] B. Smith, "An approach to graphs of linear forms (Unpublished work style)," unpublished.
- [5] E. H. Miller, "A note on reflector arrays (Periodical style—Accepted for publication)," *IEEE Trans. Antennas Propagat.*, to be published.
- [6] J. Wang, "Fundamentals of erbium-doped fiber amplifiers arrays (Periodical style—Submitted for publication)," *IEEE J. Quantum Electron.*, submitted for publication.
- [7] C. J. Kaufman, Rocky Mountain Research Lab., Boulder, CO, private communication, May 1995.
- [8] Y. Yorozu, M. Hirano, K. Oka, and Y. Tagawa, "Electron spectroscopy studies on magneto-optical media and plastic substrate interfaces(Translation Journals style)," *IEEE Transl. J. Magn.Jpn.*, vol. 2, Aug. 1987, pp. 740–741 [*Dig. 9th Annu. Conf. Magnetism Japan*, 1982, p. 301].
- [9] M. Young, *The Technical Writers Handbook*. Mill Valley, CA: University Science, 1989.
- [10] (Basic Book/Monograph Online Sources) J. K. Author. (year, month, day). *Title* (edition) [Type of medium]. Volume(issue). Available: [http://www.\(URL\)](http://www.(URL))
- [11] J. Jones. (1991, May 10). *Networks* (2nd ed.) [Online]. Available: <http://www.atm.com>
- [12] (Journal Online Sources style) K. Author. (year, month). *Title. Journal* [Type of medium]. Volume(issue), paging if given. Available: [http://www.\(URL\)](http://www.(URL))

