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Research paper

Influence of Treated Natural Jute Fiber on Flexural Properties of Reinforced Concrete Beams

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Abstract

India is one of the largest producers of jute, its potential use in many branches of engineering should be developed for the prosperity of the nation. The recent trends in utilizing the natural fibers has increased due to its advantages over synthetic fibers due to low cost, low environment hazard and easy availability. The properties of the fiber is improved by treating the jute fiber with alkali and latex polymer. Since, very few studies been conducted using the treated jute fiber concrete, an experimental work was carried with 0.6% as optimum percentage of treated jute fibers based on the mechanical properties of concrete. The influence of flexural characteristics of concrete was compared with control beams and beams cast with fibers in whole area and also only in tension zone of beam for M20 and M25 concrete grade. The beams with fibers of whole area had better strength, stiffness characteristic than the control beam and the beam with fibers in tension zone only. The initial cracking load was increased by 12.92% and 11.23 % and ultimate load was increased by 6.94% and 7. 20% for the beams cast with fibers in whole area for M20 and M25 grade of concrete, respectively.

Keywords: *Jute fiber, alkali, Polymer Latex, flexural strength*

1. Introduction

Production of a durable and economical natural fiber has become trend and an alternate to synthetic fiber which exploits the environment before and after it production [1–3]. The nation India tops the table worldwide in producing and consuming country and accounts for about 60% of the world production of jute fibres. [4]. Natural fibers such as sisal, coconut, sugar-cane bagasse, hemp, jute are reported to yield improved mechanical strength of the cement based composites [5–8]. Reviewing the literature, it is understood addition of natural fibers enhances the mechanical properties, post-cracking resistance, high energy absorption most suitable for seismic areas, fatigue strength and also it is economy and using manufacturing of precast light weight walls and roofing [9-13]. In addition to the above advantage it remains difficult to understand its durability aspect of natural fibers and also the disperse of the fibers in the concrete [14-18].The present study uses the natural fibers which was treated with optimum dosage of alkali solution at room temperature. Alkali treated jute fibers were again treated with polymer latex to improve its durability and mechanical characteristic of treated jute fiber. [19–22].

2. Experimental Research

Raw Materials

Ordinary Portland cement of 43 grade conforming to BIS 8112 [23]. River sand confirming to Zone II specifications [24] was used as fine aggregates and crushed granite was used as coarse aggregate. Coarse aggregate of two sizes: 20 mm and 12.5 mm, were used in a mix proportion of 50% each. The properties of the aggregate are shown in Table 1.

Table 1: Properties of Aggregate

Content	Coarse Aggregate		Fine Aggregate
	20 mm	12.5 mm	
Density g/cm^3	2.65	2.643	2.59
Fineness modulus	7.07	6.72	2.70
Specific Gravity	2.70	2.72	2.65
Water Absorption	0.40	0.40	0.60

Natural Fibers and Chemical treatment

Fibers were made out of the jute were considered, these fibers were chemically treated to enhance their durability and tensile strength properties of raw jute. These jute fibers were cut into a length of 50 mm and then subjected to chemical treatment. The chopped raw fibers were soaked in 0.5% alkali solution at room temperature. The fibers were kept immersed in the alkali solution for 24 h. Then distilled water was used to remove the excess alkali present in the fiber by washing it several times till the pH in the fiber was 7.0. Then the fibers were dried in controlled manner for room temperature and the by oven drying for 24 h for each process. Alkali treated jute fibers were dipped into 0.5% polymer latex (carboxylate styrene-butadiene copolymer based polymer latex) for 24 h at room temperature condition. Then fibers were dried till the moisture content was driven. Table 2 shows mechanical properties of raw jute fibers and treated jute fibers. There was meager variations in the mechanical properties between the raw and treated jute fibers.

Mix Proportions

The concrete mix design for M20 and M25 was carried out based on BIS 10262-2009 [25]. The ratio of material were fixed for each grade of concrete and the addition of treated fibers with respect to cement are shown in Table 3.

Experimental Set Up and Test Procedure

The experiments were conducted in two sets. In first set, the fresh properties and hardened properties of two different concrete grades were studied for three different percentage of fiber content to optimize the fiber content. In the second phase, flexure behavior study was conducted on three types of concrete beams based on the distribution of fibers for each concrete grade. The first one was control beam (CCB), the second one was with the presence of treated jute fiber in full length of concrete beam (FCB) and the last one was with the presence of half the depth of beams with Jute fibre reinforced concrete (at bottom) (FHCB) and remaining with normal concrete beams. The reinforcement details and experimental set up of reinforced concrete beam are shown in figure 2 &3. The test program consists of 18 beams. The span of all beams was 1500 mm with a cross section of 100 x 200 mm. These beams were reinforced with 2 bars of 10 mm diameter steel bars in tension side and 2 bars of 8 mm diameter steel bars in compression side with 6φ mm steel stirrups @ 150 mm center to center are shown in figure 2. The beam was tested under a four point loading condition. The load was applied by 30 metric ton power controlled hydraulic jack, the deflection were measured at the mid span, span by three distance by using linear variable differential transducer (LVDT). The reinforcement detailing of beams and experimental set up is shown in figure 1 and 2, respectively.

Table 2: Properties of Jute Fibres

S.No.	Property	Raw Jute fiber	Treated Jute Fibers
1	Density(g/cm^3)	1.3	1.5
2	Elongation (%)	1.7	1.8
3	Tensile Strength (MPa)	393-473	410 – 493
4	Young’s Modulus (GPa)	23.5 – 26.5	21 - 24

Table 3: Mix Proportions of Concrete

Grade of Concrete	W / C ratio	Slump in mm	TJF Content (%)	Mix Proportions) kg/m^3		
				Cement	Fine Aggregate	Coarse Aggregate
M20	0.49	50 - 75	0.00	396.75	747	1080
			0.50			
			0.60			
			0.70			
M25	0.46	50 - 75	0.00	409.78	725	1050
			0.50			
			0.60			
			0.70			

3. Results and Discussion

Workability Test

Slump test was conducted according to IS1199-1959 [25] to study the workability of concrete and to infer variation in the workability with the addition of fibers in concrete. The mix design was designed for the slump of 50 – 75 mm and the control mix was able to achieve the design slump. The addition of fibers reduces the workability when compared with the control mix but the values are well within the design slump limit. The slump results are shown in figure 3.

Mechanical Properties

The compressive strength properties of concrete were determined by testing concrete cubes after 28 days of curing in compression testing machine of 3000 kN at constant loading rate 140 kg/mm^2/min and tested according to BIS516: 2004 [26].It was observed that concrete cubes containing treated jute fiber failed at higher compressive loads as compared to control specimen. The variation with in the various percentage of addition fibers tends that at 0.6 percentage addition fibers has higher strength than the other two percentage of addition of fibers. The decrease in the strength initiates from 0.7 % this may be due to fiber agglomeration [27]. The percentage variation in the compressive strength of concrete are shown in figure 4. Based on compressive strength and the slump value the optimum percentage of addition fiber was considered as 0.6% for the further study on flexural behaviour of reinforced concrete beams.

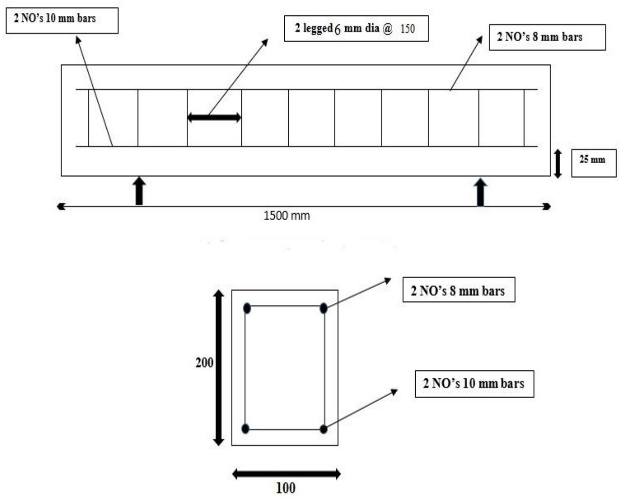

Fig. 1: Reinforcement details of beam

Fig. 2: Experimental setup for testing beams

Flexural behaviour of RCC Beams

The experimental study on reinforced concrete beam overwhelms to understand the behaviour and influence of addition of fibers, whilst, based on location of TF in the beam. Figure 5 provides details load versus deflection behaviour of M20 grade concrete and M25 grade concrete with and without TF, respectively.,

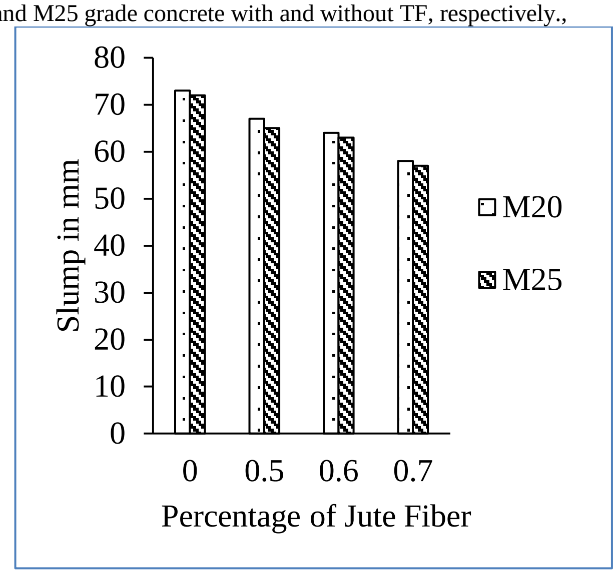

Fig. 3: Slump versus percentage of fiber content

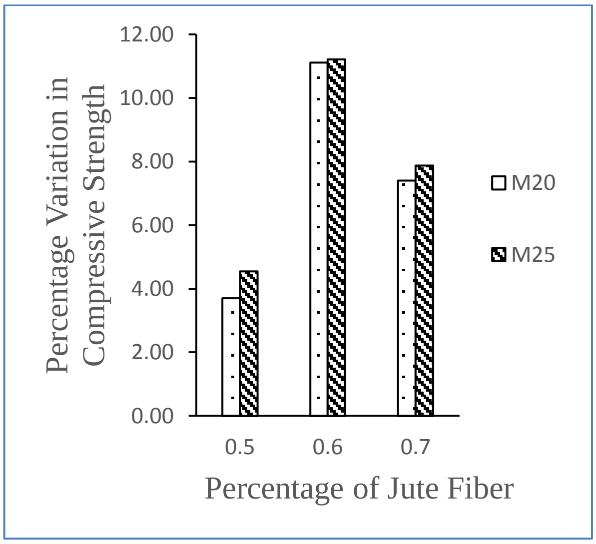

Fig. 4: Percentage variation in compressive strength and fiber content

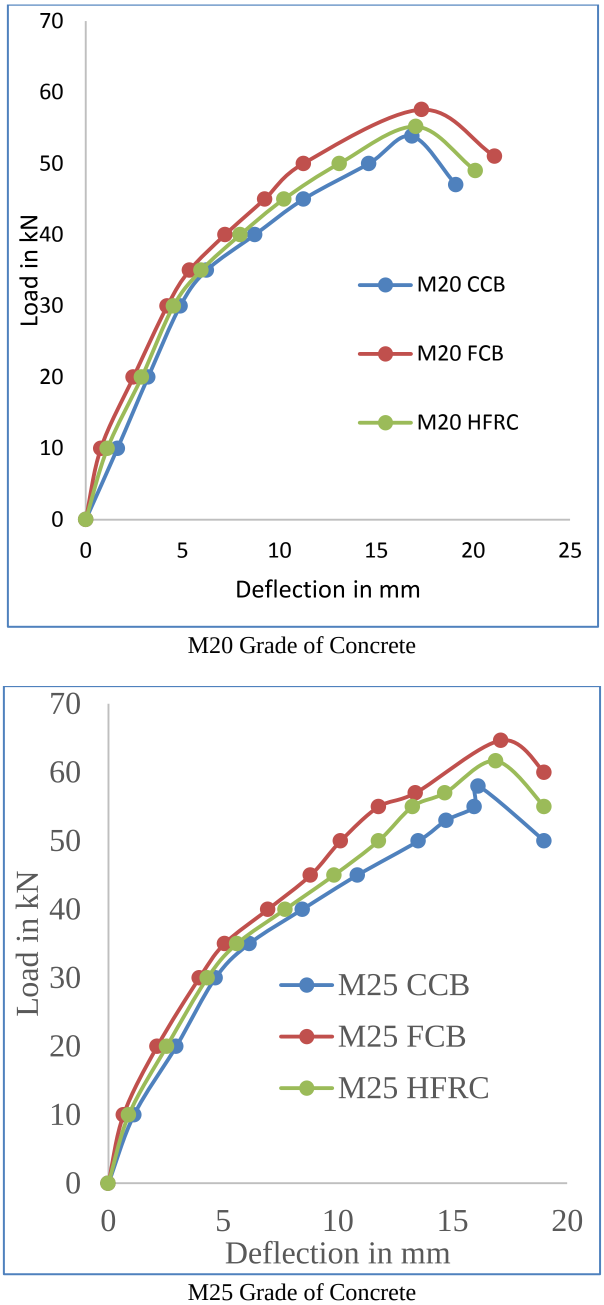

Fig. 5: Load versus deflection behaviour o[for with and without TF

The figure 5clearly depicts the presence of fiber increased the stiffness at the lower loads than the control beam, when comparing with the FRC and HFRC, the FRC beams had initial stiffness, ultimate capacity greater than the GFRC. Table 4 summaries the load and deflection at the various loading stages. The percentage increase in initial cracking load of M20 grade of concrete for FRC and HFRC were 12.92 % and 6.00 %, respectively. The ultimate load carrying capacity of FRC and HFRC beams were 6.94 % and 2.50%, respectively. Similar observations were found for M25 grade concrete, the values were slightly varying but the variations were almost similar, the initial cracking load was increased by 11.23 % and 7.29 %, respectively. The ultimate load carrying capacity of beams were increased by 7.20 % and 2.21 %, respectively. The ductility ratio of the fiber added beam is enhanced than the control beam. The ductiltity ratios were 3.86, 4.34, 4.12 for CCB, FRC and HFRC, respectively.

Table 4: Mix Proportions of Concrete

Sl. No	Grade of concrete	Specimen ID	First crack Load in kN	Deflection at first crack Load in mm	Ultimate Load in kN	Deflection at Ultimate Load in mm	Ductility Ratio
1	M20	CCB	36.16	6.82	53.83	16.84	3.86
2		FRC	40.83	7.53	57.56	17.34	4.34
3		HFRC	38.33	7.31	55.18	17.04	4.12
4	M25	CCB	38.17	7.62	60.33	14.12	3.34
5		FRC	43.02	8.21	64.67	15.19	4.34
6		HFRC	41.17	8.08	61.68	14.66	3.89

Fig. 6: Cracking pattern of beams

Cracking and Mode of Failure

Figure 6 shows the formation of crack, crack pattern and failure mode of the beams tested with and without fibers. The first crack was formed at the maximum bending moment zone and the load required was around 30 % to 40 % of the failure load. After initiation of first crack the load was further increased to study the formation of number of flexural cracks, crack patterns and crack width. The formation of crack patterns was found to be similar in all the types of beams but the number of cracks formed founds to vary between the FRC, CCB and HFRC beams. The FRC beams shows superior performance than other two types by forming less numbers of cracks and lesser crack widths. The study shows that presence of fiber on all the parts of the cross section enhances the behviour of beam under cracking and the presence of fiber delays the formation of cracks in flexure and lesser crack widths since the fiber added was acting as bridging element between the cracks.

4. Conclusions

In this study, treated jute fiber with alkali and polymer latex was used as addition as percentage to cement for 0.50%, 0.60% and 0.70 %. The optimum dosage of TJF were found experimentally based on the fresh properties, mechanical property of concrete for M20 and M25 grade of concrete.

- The slump shows a descending trend as the fiber id added in compared with Control specimen.
- The compressive strength of concrete is greater than the control specimen for all the percentage addition of fiber. But the values decreases after reaching a maximum for 0.6% addition of fiber, the decrease in compressive strength may attribute due to agglomeration of fiber beyond certain percentage.
- Optimum dosage of TJF content was 06% as an addition to cement content.
- The behviour of reinforced concrete beam under flexural was enhanced after addition of TJF.
- The presence of fiber in whole area increases the compressive strength and post cracking resistance by forming a bridge between cracks.
- The presence of TJF in whole area is more advantage than the control beam and HFRC in tension zone.

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