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Polymer modified jute fibre as reinforcing agent controlling the physical and mechanical characteristics of cement mortar

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HIGHLIGHTS

- Methodology to disperse polymer modified jute fibre homogeneously into the mortar.
- Significant improvement of CCS, MOR, and FT in jute fibre reinforced mortar.
- Substantial improvement in TI as well as the PCRE in modified mortar.
- Plausible mechanism to explain the improvement in mechanical properties.

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ABSTRACT

Polymer modified alkali treated jute fibre as a reinforcing agent, substantially improves the physical and mechanical properties of cement mortar with a mix design cement:sand:fibre:water::1:3:0.01:0.6. The workability of the mortar is found to increase systematically from 155 ± 5 mm (control mortar) to 167 ± 8 mm (0.2050% polymer modified mortar). The density of the mortar is increased from 2092 kg/m^3 to 2136 kg/m^3 with a concomitant reduction of both water absorption and apparent porosity. Optimal polymer content in emulsion (0.0513%) is found to increase the compressive strength, modulus of rupture and flexural toughness 25%, 28%, 387% respectively as compared to control mortar. Based on the X-ray diffraction and infra-red spectroscopy analyses of the mortar samples a plausible mechanism of the effect of modified jute fibre controlling the physical and mechanical properties of cement mortar has been proposed.

1. Introduction

Natural fibres as reinforcing agent in cement matrix are nowadays being considered as effective alternative to steel and other inorganic synthetic fibres [1,2]. Natural fibres such as sisal, coconut, sugar-cane bagasse, hemp, jute are reported to yield improved mechanical strength of the cement based composites [3–7]. Additionally they also enhance the post-cracking resistance, yield high-energy absorption characteristics and improve the fatigue resistance of cement based composites [8–10]. Reviewing the literature, it remains difficult to disperse the natural fibre into cement matrix and also their long term durability in cement matrix is yet to be investigated [11–14]. The potential application of natural fibre reinforced cement composites are limited to those area where energy must be absorbed or the areas prone to impact damage. Accordingly, natural fibre reinforced cement composites are most suitable for shatter and earthquake resistant construction, foundation floor for machinery in factories, fabrication of light weight cement based roofing and ceiling boards, wall plaster, and construction materials for low cost housing [15].

Variety of factors influences the physical and mechanical properties of natural fibre reinforced cement composites. These factors may be grouped according to (i) the type and characteristics of reinforcing fibres, (ii) nature of the cement based matrix and mix design, and (iii) way of mixing, casting and curing of the composites [15]. Among these parameters, the compatibility between the fibre and cement based matrix leading to a homogeneous distribution of the reinforcing fibres remains one of the most dominating factors that influences the mechanical properties of these composites [16]. The fibre–matrix compatibility is dominated by the chemical composition of the reinforcing fibre together with their surface properties. Due to the parametric dependence of so many factors, the wide scattering in the mechanical properties of natural fibre reinforced cement composites as tabulated in Table 1 seem to be obvious.

In the present work, we aim to investigate the effect of jute fibre as a reinforcing agent to cement mortar. For homogeneous distribution of jute fibre into the cement matrix we have modified both the chemical composition as well as surface properties of jute fibre

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Table 1
Comparative study of mechanical behavior of different fibre reinforced cement composites.

Fibre type	Type of modification	Mechanical properties						Reference
		CCS[a] (MPa)	MOR[b] (MPa)	MOE[c] (GPa)	FT[d] (kJ/m^2)	TI[e]	PCRE[f] (J)	
Eucalyptus	–	31.1	3.87	–	0.53	–	–	[2]
Hemp	–	32.65	4.62	–	0.73	1.86	–	[6]
Jute	–	27.97	4.44	–	0.62	–	–	[7]
Kraft banana	–	–	21.7	6.7	0.59	–	–	[10]
E grandis	–		22.2	8	1.5	–	–	[17]
Kenaf (1.2, %)		33.4	4.7	–	1.3	–	–	[18]
Kraft	APTS	–	12.1	16.3	0.82	–	–	[12]
Coconut husk	$CaCl_2$	4.1	2.2	1.1	–	–	–	[13]
Bagasse fibre	SBR, Vinyl ester		14.5	6.8				[14]
Jute	Carboxylated SBR	35.4	9.1	0.5	0.63	1.69	0.102	Present research

[a] Compressive strength.
[b] Modulus of rupture.
[c] Flexural modulus.
[d] Fracture toughness.
[e] Toughness index.
[f] Post cracking resistance energy.

by a combined dilute alkali and polymer emulsion treatment. The effect of fibre modification on the physical and mechanical properties of cement mortar has been investigated. Moreover, the effect of chemical treatment of the reinforcing fibres on their durability in highly alkaline cement environment has also been investigated. Finally, the plausible mechanism of such fibre treatment controlling the physical and mechanical properties of cement mortar is elucidated.

2. Experimental

2.1. Preparation of alkali and polymer modified jute fibre reinforced cement mortar

Portland pozzolana cement confirming with IS 1489-1991 (reaffirmed 2005) (Ambuja cement) [19] was used as the binder material for the preparation of cement mortar. The oxide composition of this cement is shown in Table 2. The local river sand was used for the preparation of cement mortar. This sand did not contain any organic substances which might affect cement hydration reaction. To evaluate grading zone and average particle size of sand, sieve analysis was performed. From the sieve analysis (Fig. 1), it was confirmed that the used sand is in grading zone II with average particle size 0.3 mm. TD-4 grade jute fibres were used as reinforcing agent. As received jute fibres, being long enough, could not be used as reinforcing agent in cement. Therefore to use the jute fibre as reinforcement in cement composite, the long jute fibres were chopped into 5 mm length. The average diameter of used jute fibre was 0.062 ± 0.014 mm.

Table 2
The oxide composition of Portland pozzolanic (Ambuja) cement.

Composition	SiO_2	CaO	MgO	Fe_2O_3	Al_2O_3	C	L.I.[a]
Weight (%)	27.28	50	1.96	6.18	9.20	0.76	2.66

[a] Loss of ignition.

The treatment composition of jute with alkali and polymer latex is shown in Table 3. First the requisite amount of jute as mentioned in Table 3 was soaked with the 0.5% alkali solution following which the spent alkali solution was decanted out after 24 h of soaking. Next the respective amounts of Sika latex containing 41% solid (carboxylated styrene butadiene (SBR)) was diluted with 1000 ml of water and added to the alkali soaked wet jute.

The cement mortar was prepared following the composition shown in Table 4. In the mix design the weight fraction of cement:sand:fibre:water was kept 1:3:0.01:0.6. The total alkali and polymer treated jute (as shown in Table 3) were mixed with half part of the cement required to make the mortar. A mechanical mixer was used to make uniform slurry after 10–15 min mixing. The required amount of sand, rest of the cement and additional amount of water was mixed thoroughly with the slurry for another 10–20 min. The fresh mortar thus prepared was cast immediately in 110 mm (length (l)) × 20 mm (breadth (b)) × 20 mm (depth (d)) mould for flexural specimen and 70.6 mm cubic mould for compressive specimen. The mortar samples were allowed to set in the moulds for 24 h at ambient temperature (30 ± 2 °C). The samples after setting were removed from the mould and water cured for 7, 28, 42, and 90 days. After curing, the mortar specimens were dried under ambient condition. For the characterization of polymer modified jute fibre reinforced mortar, minimum six samples of each batch were tested.

As shown in Table 4, nine different formulations (viz., 1–9) were used for the preparation of the mortar samples. In these mortar samples, the ratio of cement:sand:fibre were kept constant, however, the solid polymer: water (weight to volume) ratio were varied. The solid polymer content in emulsion (defined as weight of solid polymer in 100 ml water) was varied in between 0.0257% and 0.205% (w/v). In this experiment, for each formulation 6 samples were fabricated for each test.

To evaluate the durability of the alkali polymer modified jute fibres in alkaline cementitious medium, the combined alkali polymer modified jute reinforced cement paste was prepared with the mix design cement:alkali treated jute:water 1:0.01:0.6. In this test 100 mm long jute fibres were used. Initially the jute fibres were treated with 0.5% NaOH solution for 24 h followed by mixing with polymer

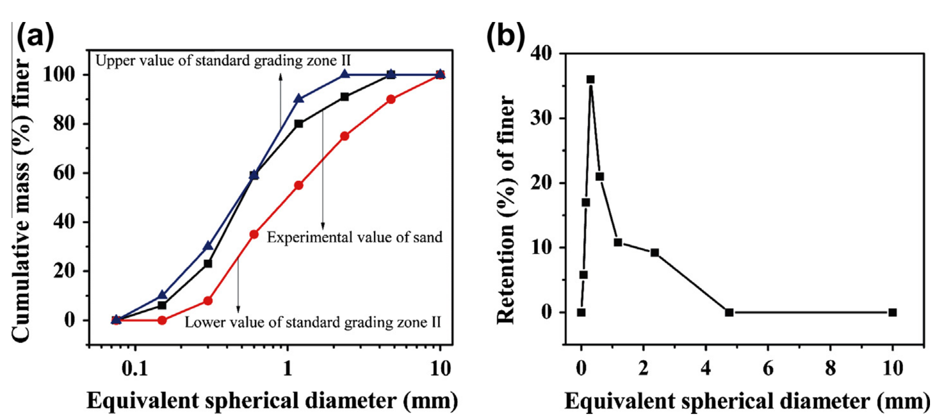

Fig. 1. (a) A comparative study of cumulative mass (%) passing of fine aggregate (sand) through the equivalent spherical diameter sized sieve with the standard value of grading zone II, (b) retention of fine aggregate on different equivalent spherical diameter sized sieve.