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Jute–Basalt Hybrid Fibre Wrapping for Seismic Retrofitting of Concrete Columns: A Critical Review with a Preliminary Cube Test

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Abstract

Many reinforced concrete (RC) buildings in India were built before ductile earthquake detailing was required or enforced, and their columns are a critical weak point. Wrapping columns in fibre-reinforced polymer (FRP) is an established retrofit, but carbon and glass FRP are costly. This paper reviews published evidence on lower-cost alternatives, focusing on a hybrid jute/basalt wrap. In the study reviewed, a wrap of two jute and two basalt layers raised the axial capacity of 150 x 300 mm concrete cylinders by 63.64 percent and their energy absorption by 287 percent, against 36.12 percent for a two-layer basalt wrap, and it kept a confinement effectiveness of 163 to 213 percent after 120 days in water, alkali, seawater and acid. The hybrid used four layers against two for the basalt-only wrap, so part of its advantage may come from layer count. A related study reported about 23 and 57 percent for glass and carbon wraps. These values come from separate studies and are indicative only. We also ran a preliminary cube test: at 3 days an M20 cube with loose jute and basalt strands reached 13.16 MPa against 7.67 MPa for a plain control. This is one air-cured cube per group and not a retrofit test, so it is treated as a first observation only. Natural/basalt hybrids have been tested on cylinders and beams, but we found no cyclic tests on RC columns, no cost data for Indian conditions, and no test of a low-resin option such as a fibre-reinforced jacket. This paper contributes a consolidated comparison, an explicit list of these gaps, a proposed test programme, and one exploratory observation.

Keywords: seismic retrofitting; FRP confinement; jute fibre; basalt fibre; hybrid composites; RC columns

1. Introduction

India lies in a seismically active region divided into Zones II (lowest) to V (highest) [1]. Much of the existing RC building stock was built before the ductile detailing of current practice [2] was required or consistently followed, and demolishing and rebuilding is rarely feasible, so strengthening columns, which carry the building's weight, is the practical option. Wrapping a column in FRP confines the concrete and raises its strength and, more importantly in earthquakes, its deformation capacity [3]. Carbon FRP is the usual choice but is expensive and energy-intensive to produce [4], which limits its use on public buildings. Natural fibres such as jute and flax are the most-used plant fibres in this field [4], and basalt FRP has been reported to match carbon FRP in column tests at about one fifth of the material cost [5]. Hybrid wraps that pair a natural fibre with basalt have begun to appear, mainly on cylinders and beams: jute with basalt on cylinders [6] and on RC beams [7], and flax with basalt on cylinders [8] and, judging by its title, on columns [9]. The research gap is therefore not the idea of a natural/basalt hybrid but the lack, in the sources we found, of (a) cyclic tests of jute/basalt wraps on RC columns, (b) cost and durability data for Indian conditions, and (c) any test of a low-resin option such as a fibre-reinforced jacket. This paper (i) compares the published evidence in one place, (ii) reports a small preliminary cube test of our own with its limits stated, and (iii) sets out a programme to close these gaps before such a wrap can be recommended.

2. Literature Review

2.1 Confinement and natural and basalt fibre wraps

A column loaded in compression expands sideways as it nears failure (Figure 1), and a wrap whose fibres run around the column resists this expansion, so the column fails more gradually. This ductility is what matters in an earthquake [3], [10]. A mixed review of 87 experimental studies concluded that bio-based FRPs can effectively strengthen concrete beams and columns, with flax and jute the most used fibres, and flagged durability, cost and the lack of bio-based

matrices as open issues [4]. Circular and square specimens confined with jute-polyester hybrid FRP gained 18 to 161 percent in strength depending on concrete strength, shape and number of layers, with far larger strain gains [11]. Tests on 63 cylinders confined with jute, hemp and cotton FRP found the confinement effective, especially with jute, and showed that standard FRP strength models needed modification because natural fibres have a nonlinear tensile stress–strain response [12]. For basalt, FRP wraps on cylinders gave strain-softening behaviour with little strength gain in the configurations tested, but an ultimate strain up to five times the unconfined peak strain, and full wrapping was clearly better than discrete strips [13]. At member level, six RC columns tested under simulated seismic loading showed equal or better seismic performance with basalt FRP than with carbon FRP, with more stable hysteresis loops and greater energy dissipation than the unretrofitted column, which failed in brittle shear [5].

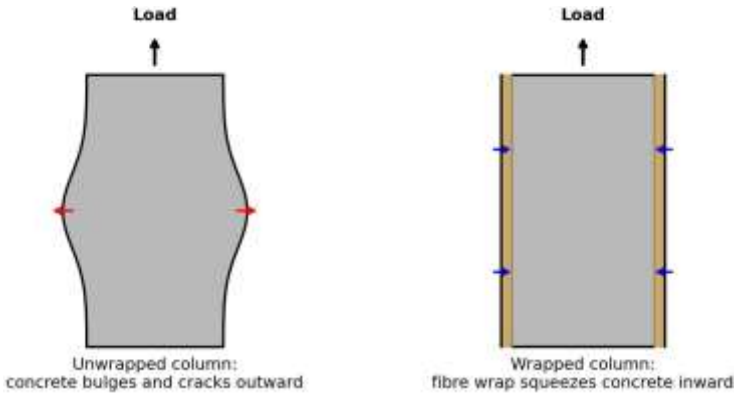


Figure 1: Schematic of confinement: an unwrapped column bulges and cracks, while a wrapped column is held in by the fibre hoop action (authors' illustration).

2.2 The hybrid jute/basalt wrap

Varma et al. [6] wrapped 150 x 300 mm concrete cylinders by hand lay-up with jute as the inner layers and basalt as the outer layers, bonded with a two-part epoxy and cured for 7 days. Jute is placed inside because the inert basalt can protect it from moisture. The wrap of two jute and two basalt layers raised axial capacity by 63.64 percent and energy absorption by 287 percent, against 36.12 percent for two basalt layers alone [6]. After 120 days in 5 percent sulphuric acid, 7 percent sodium hydroxide, 3.5 percent sodium chloride and potable water, the authors report confinement effectiveness (wrapped strength as a percentage of unwrapped strength) of 163, 164, 166 and 213 percent for water, alkali, seawater and acid, so wrapped specimens were still about 1.6 to 2.1 times as strong as unwrapped ones [6]. A related study reported about 23 percent for glass FRP and 57 percent for carbon FRP on comparable cylinders [14]. Figure 2 compares these values. They come from separate studies with different concrete, resin and layers, so the ranking is indicative only. In particular, the hybrid used four layers and the basalt-only wrap two, so part of the difference may come from layer count and not from hybridising, and Varma et al. also tested other jute/basalt combinations that we do not report [6]. Energy absorption, the area under the load-deformation curve, is the figure that matters most for earthquakes, because seismic resistance depends on how much energy a column can absorb before failing and not only on peak load [6]. Other natural/basalt hybrids point the same way. Basalt/flax FRP made by filament winding had linear stress–strain behaviour, unlike the non-linear response of flax alone, with improved tensile properties, and the layer arrangement affected the confinement of cylinders [8]. In 18 RC beams tested in four-point bending, a jute–basalt hybrid U-wrap gave 39.6 percent higher load capacity than the control, and a basalt full wrap up to 36.8 percent [7]. A 2026 study tested flax/basalt hybrid FRP-confined columns with different fibre layup and orientation [9]; we could read only its title, so its results are not discussed. Table 1 lists the studies and Table 2 gives the durability values.

Table 1: Published studies most relevant to a jute/basalt wrap (values as reported by the authors).

Study	Fibre system	Specimens	Main reported result
Wahab et al. [11]	Jute-polyester hybrid FRP	32 specimens, circular and square	Strength 1.24 to 2.61 times unjacketed
Jirawattanasomkul et al. [12]	Jute, hemp, cotton FRP	63 cylinders, 1 to 6 plies	Effective, especially jute; strength models needed modification
Campione et al. [13]	Basalt FRP wraps	Concrete cylinders	Strain up to 5 times peak; little strength gain
Ouyang et al. [5]	Basalt and carbon FRP	Six RC columns, simulated seismic load	Basalt equal or better than carbon
Kavitha et al. [14]	Glass and carbon FRP	Concrete cylinders	About +23% (glass), +57% (carbon)
Xia and Xian [8]	Basalt/flax hybrid FRP (filament wound)	Concrete cylinders	Linear stress–strain; layer order affected confinement
Saingam et al. [7]	Jute–basalt hybrid FRP, basalt FRP	18 RC beams, four-point bending	Hybrid U-wrap +39.6% capacity; basalt full wrap up to +36.8%
Varma et al. [6]	Jute/basalt hybrid (2 jute + 2 basalt layers); basalt-only 2 layers	150 x 300 mm cylinders	+63.64% strength, +287% energy; basalt only +36.12%

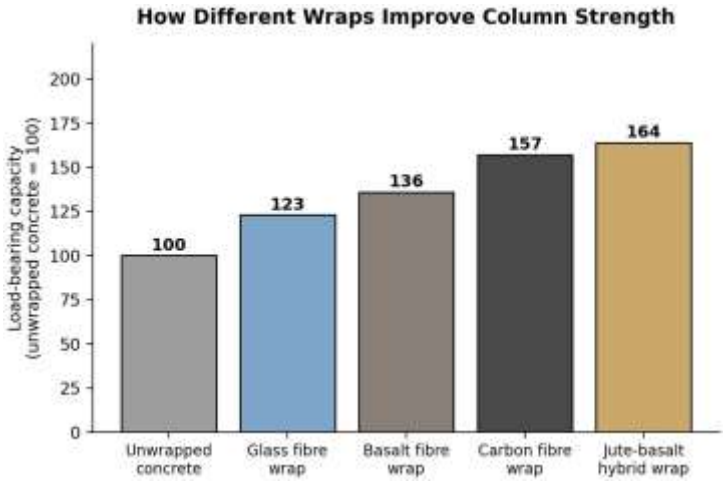


Figure 2: Relative load capacity of wrapped cylinders (unwrapped = 100) from published values [6], [14]; hybrid = 2 jute + 2 basalt layers, basalt only = 2 layers; separate studies, indicative only.

Table 2: Durability results of the hybrid wrap [6]: confinement effectiveness (wrapped strength as a percentage of unwrapped strength) after 120 days of immersion.

Exposure	Solution	Confinement effectiveness (%)	Wrapped / unwrapped strength
Water (baseline)	Potable water	163	about 1.6 times
Alkaline	7% sodium hydroxide	164	about 1.6 times
Seawater	3.5% sodium chloride	166	about 1.7 times
Acid	5% sulphuric acid	213	about 2.1 times

The values for water, alkali and seawater are close to the 63.64 percent gain measured without exposure, which suggests the wrap lost little effectiveness in those environments. Exposure lasted 120 days, so longer-term behaviour is unknown.

2.3 Fibres mixed into concrete

Short fibres can also be mixed into concrete. For jute, a compressive gain of about 15 percent was reported at 0.10 percent fibre volume with fibres of 15 mm or less in a 1 : 1.5 : 3 mix, while longer fibres and higher dosages reduced strength because the fibres ball up and leave the concrete porous [15]. For basalt, a review reports mixed compressive results, with optimum dosages near 0.1 to 0.2 percent and larger gains in tensile and flexural strength [16]. Fibre mixed into concrete therefore gives modest compressive gains at best, which is the background for reading our own result.

3. Methodology

3.1 Literature search and selection

This is a narrative review, not a systematic one. In 2026 we searched publisher sites and web search engines (ScienceDirect, Wiley, Springer, MDPI, SAGE, Nature and PubMed Central listings) with combinations of the terms jute, basalt, flax, hybrid, FRP, confinement, concrete cylinder, RC column, retrofit and fibre-reinforced concrete. We kept English-language, peer-reviewed experimental or review papers that reported specimen details and quantitative results, plus the relevant Indian Standards; no start date was set, but nearly all included studies are from 2014 onwards, apart from one foundational confinement model. Reading depth varied: because several publisher sites restricted access, some papers were read in full and others at abstract or publisher-summary level. Values are quoted as reported and were not recomputed. Concrete grade, resin, number of layers and specimen shape differ between studies and are not all tabulated, so comparisons are indicative only.

3.2 Design and purpose of the cube test

A hybrid wrap could not be tested on columns with the equipment and time available, so we ran a small test of the same two fibres in concrete. This tests fibre inside new concrete; it is not a retrofit test, because retrofitting strengthens an existing hardened member from outside. Its relevance is as a first check of the material a fibre-reinforced jacket would use.

3.3 Materials, mix and test procedure

Two 150 mm cubes were cast from a nominal M20 mix of 1 : 1.5 : 3 (Portland pozzolana cement : sand : 20 mm aggregate) [17], with water of about 8 to 10 percent by weight of the dry materials (about 500 ml), mixed by hand on a tray. Each cube was placed in three layers of about 50 mm, each compacted with 35 strokes of a 16 mm x 600 mm tamping rod [18]. In the fibre cube a small handful of loose jute and basalt strands, cut to a few centimetres, was placed at each layer (quantity and length estimated, not weighed; Figure 3). Moulds were oiled, the cubes de-moulded after 24

hours and air-cured, and both were crushed at 3 days in a 1000 kN compression testing machine (Table 3).

Table 3: Details of the preliminary cube test.

Item	Details
Specimens	Two 150 x 150 x 150 mm cubes: one plain (control), one with jute-basalt fibre
Mix	M20, nominal 1 : 1.5 : 3 (PPC : sand : 20 mm aggregate); water about 8-10 percent by weight of dry materials (about 500 ml); mixed by hand on a tray
Placing and compaction	Three layers of about 50 mm; 35 strokes per layer with a 16 mm x 600 mm rod
Fibre	Small handful of loose jute and basalt strands per layer, a few cm long (estimated, not weighed)
Curing and age	Moulds oiled; de-moulded after 24 h; air-cured; tested at 3 days
Machine	Compression testing machine, 1000 kN capacity
Not reported here	Cement grade, fibre dosage by mass, loading rate, ambient conditions during curing, and casting and test dates

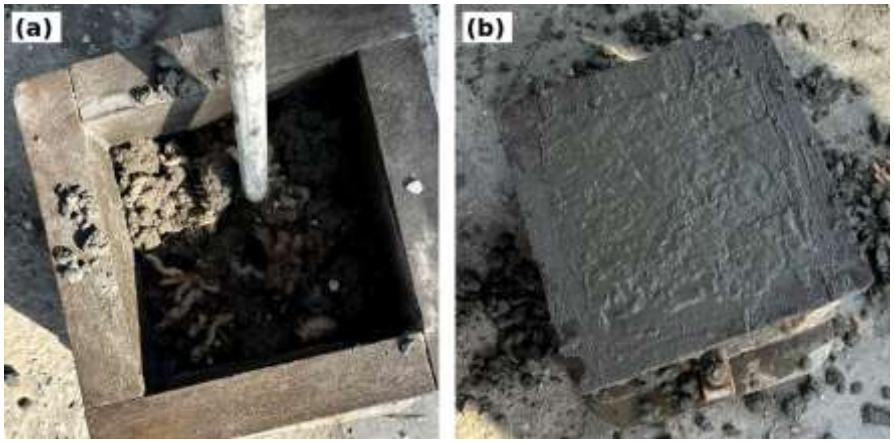


Figure 3: Casting of the cubes: (a) tamping the first layer of the fibre cube, with strands visible; (b) a cube after finishing in the 150 mm mould.

4. Results

4.1 Compressive strength of the cubes

Table 4 and Figure 4 give the 3-day results. Strength is failure load divided by the 22,500 mm2 loaded area (150 x 150 mm); the loads in Table 4 are calculated from the strengths, not read from the machine. The plain cube reached 7.67 MPa and the fibre cube 13.16 MPa, so the fibre cube was 71.6 percent stronger ((13.16 - 7.67) / 7.67). At failure the plain cube broke apart, while the fibre cube cracked but stayed largely in one piece.

Table 4: Three-day compressive strength of the 150 mm cubes (one cube per group; area 22,500 mm2).

Specimen	3-day strength (MPa)	Implied load (kN)	Difference
Plain concrete cube (control)	7.67	172.6	Baseline
Cube with jute-basalt fibre	13.16	296.1	+71.6 percent

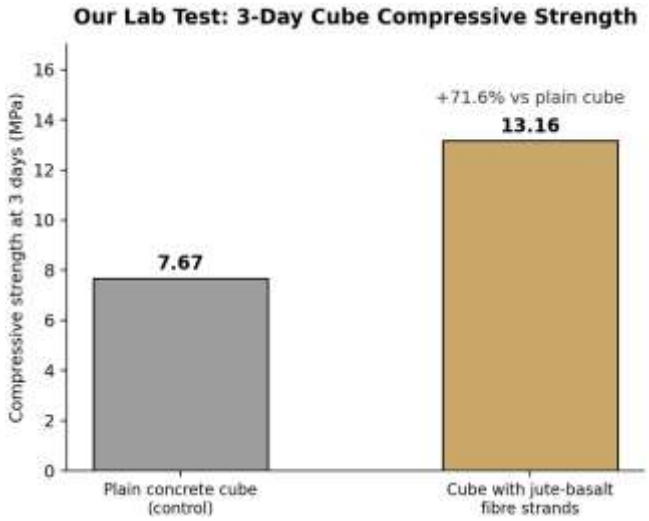


Figure 4: Three-day compressive strength of the plain and fibre cubes (one cube per group; air-cured).

5. Discussion and Research Gaps

5.1 Interpretation of the cube test

The size of the difference is not credible as a material property: it is far above the roughly 15 percent reported for jute in concrete at its best dosage [15] and the mixed basalt results [16]. We tested one cube per group where three per age is usual [18], both cubes were air-cured instead of water-cured, and the fibre was not weighed, so cube-to-cube variation and test conditions may explain much of the gap. We make no claim about 28-day strength. The result is a first observation that motivates the replicated test proposed in Section 5.4, not evidence of a gain.

5.2 What the evidence supports

Taken together, the published studies support three limited conclusions. First, natural-fibre FRP, including jute, can confine concrete effectively [4], [11], [12]. Second, basalt FRP gives useful confinement and, in the one column study reviewed, seismic performance comparable to carbon FRP [5], [13]. Third, the hybrid wrap gave the highest cylinder-level strength gain among those compared (with more layers than the basalt-only wrap), a large energy absorption gain and good retention of effectiveness after 120 days of exposure [6], [14]. The rationale for the hybrid is plausible: the inert basalt outer layers can protect the jute from moisture [6], and jute is the low-cost fibre [4]. Whether the benefit comes from hybridising or simply from the larger number of layers has not been separated.

5.3 What it does not yet support

The evidence does not yet justify recommending the hybrid wrap for real buildings. The strongest hybrid result is from axially loaded plain cylinders [6]; in the sources we found, jute/basalt wraps have been tested only on cylinders [6] and beams [7], and not on RC columns under cyclic lateral load. Gains on small plain cylinders do not transfer directly to RC columns, where steel, cover, corner radius and section shape affect confinement. The epoxy needed to bond the wrap is a manufactured product, so claims of a fully local system need checking. No study reviewed gives a cost for the hybrid wrap; the cost advantage of basalt over carbon is stated by the authors of one column study [5] and the lower embodied energy of natural fibres by a review [4], and both are indirect for the hybrid.

5.4 Two routes to a retrofit and a proposed programme

There are two routes to a retrofit. In wrapping, fibre sheets are bonded around an existing column, as in the published studies. In jacketing, a new concrete layer is cast around the column, and a fibre-reinforced jacket would use material like that of our cube test, with no resin or imported fabric. Jacketing is a commonly used strengthening method for RC

columns, but a fibre-reinforced jacket for this purpose is our proposal and not an established method, and it would depend on bonding to the old column. We propose: (a) three or more water-cured specimens per group at 7 and 28 days, comparing plain concrete, fibre mixed in as in our test, and plain concrete cured first and then wrapped externally with jute cloth and basalt; (b) a fibre-reinforced jacket cast around a cured, roughened core, against a plain jacket and an unjacketed control; (c) column tests under axial and cyclic loading; and (d) a cost and durability study under local conditions. Only the externally wrapped group in (a) and the tests in (c) represent retrofitting.

5.5 Limitations

This is a narrative review and may have missed relevant studies; the quoted values were not independently verified or re-analysed. The reference list is selective, some papers were read at abstract level, and concrete grades were not extracted for every study. Our experiment is a single 3-day test with one air-cured cube per group and an estimated fibre quantity, and it does not test retrofitting. No column testing or 28-day testing was done. The paper therefore does not claim that the hybrid wrap or the fibre jacket is proven, only that the published evidence is encouraging and that the gaps above need to be closed.

6. Conclusions

Published tests show that a hybrid wrap of two jute and two basalt layers raised cylinder strength by 63.64 percent and energy absorption by 287 percent, kept a confinement effectiveness of 163 to 213 percent after 120 days of exposure, and showed larger gains than the glass, carbon and basalt-only wraps reported in separate studies, although the hybrid used four layers against two for basalt-only and the studies are not directly comparable. These cylinder results come from one group; related jute–basalt work on RC beams gave flexural gains of about 40 percent [7]. In the sources we found, the hybrid wrap has not been tested on RC columns under cyclic loading or costed. Our preliminary cube test found a higher 3-day strength with loose jute and basalt strands (13.16 against 7.67 MPa), but it was one air-cured cube per group with unmeasured fibre content and is a prompt for further work, not a finding.

Declarations

Author contributions: Both authors contributed equally to the conceptualisation, literature review, laboratory work and writing. Funding: This research received no specific funding. Conflict of interest: The authors declare no conflict of interest. Data availability: The cube strengths are in Table 4, and the laboratory record is available from the corresponding author on reasonable request. Acknowledgements: The authors thank those who gave access to the compression testing machine.

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