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Effect of Jute Fibre Addition on Fresh Properties, Mechanical Strength, and Elevated Temperature Behaviour of Self-Compacting Concrete (SCC)

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ABSTRACT

Self-Compacting Concrete (SCC) is an advanced concrete technology that achieves consolidation under its own weight without mechanical vibration, providing superior uniformity and reliability in structural applications [19],[4]. The incorporation of jute fibre India's most abundantly produced bast fibre at 1.1 million tonnes annually [17] into SCC offers a sustainable strategy for improving post-crack toughness and ductility while utilising agricultural by-products. This paper presents a systematic experimental investigation of SCC incorporating jute fibre at 0.5%, 1.0%, and 1.5% volume fraction (V_f) in a fly ash-blended SCC mix (30% FA replacement), evaluating: fresh properties (slump flow per BS EN 12350-8 [1]) and V-funnel per BS EN 12350-9 [2])); hardened properties at 7 days (compressive strength at room temperature); and 28-day mechanical properties (compressive IS 516 [11]), split tensile IS 5816 [12]), flexural IS 516 [11])) at room temperature (RT = 27°C), 100°C, and 200°C. Principal findings: (i) jute fibre at 1.0% V_f achieves the highest compressive strength (38.4 MPa, +6.1% over reference SCC 36.2 MPa) satisfying IS 456 M30 [10]); (ii) split tensile improves by 10.7% (+JF-1.0%) and flexural by 8.9% at 28 days RT; (iii) EFNARC SF2 class compliance [4]) is maintained only at ≤ 0.5% V_f jute (slump flow 682 mm at 0.5% vs. 648 mm at 1.0%); (iv) at 200°C, JF-1.0% retains 79.2% compressive strength (30.4 MPa), slightly better than plain SCC (78.2%, 28.3 MPa); (v) jute fibre improves crack distribution and failure ductility at all temperatures, delaying catastrophic failure compared to plain SCC [3],[23]). A comprehensive photographic and graphical documentation is provided covering all test methods, specimen types, failure patterns, and hardened property trends.

Keywords Jute Fibre SCC [3],[17], Self-Compacting Concrete [19],[4], EFNARC [4], Elevated Temperature [25],[20], Compressive Strength [11],[10], Slump Flow [1],[4], V-Funnel [2],[4], Fly Ash [21],[24], IS 456 [10], Residual Strength [25],[23].

INTRODUCTION

Concrete is the world's most consumed construction material, with global annual production exceeding 10 billion tonnes **[8]**). Self-Compacting Concrete (SCC) represents a significant advancement in concrete technology, achieving full consolidation under its own weight through gravity-driven flow, eliminating mechanical vibration **[19]**). Developed by Okamura and Ouchi **[19]**) in Japan in the 1980s, SCC now finds widespread application in bridge decks, tunnels, precast elements, and buildings with dense reinforcement where conventional vibration would be impractical or unreliable **[30],[4]**.

Despite SCC's superior placement characteristics, the same fluid consistency that enables self-compaction limits its post-crack toughness compared to conventional vibrated concrete. The higher paste volume and lower aggregate-to-paste ratio of SCC makes it inherently more brittle a structural safety concern for elements subject to impact, seismic loading, or fire **[3],[29]**). Natural fibre reinforcement addresses this limitation by providing crack-bridging resistance that transforms the brittle failure mode into a pseudo-ductile response **[3],[7]**.

Jute (Corchorus capsularis) is the premier bast fibre of India **[17]**). India produces over 1.1 million tonnes annually, primarily in West Bengal, Bihar, and Assam, making it the world's largest jute producer **[17]**). Jute's tensile strength (200–450 MPa), moderate elastic modulus (10–30 GPa), and relatively high lignin content (12–15%) providing reasonable alkali resistance make it suitable for concrete reinforcement at low volume fractions **[3],[7]**). Its very low cost (₹15–25/kg) compared to ₹50–80/kg for synthetic polypropylene fibres makes jute-SCC a cost-effective sustainable solution for the Indian construction sector **[17]**.

The elevated temperature behaviour of jute-fibre SCC is a critical structural fire engineering consideration. Buildings in India face fire risks that can expose structural elements to 100–600°C over their service life. Understanding how jute-SCC behaves at 100°C (initial moisture loss, early dehydration) and 200°C (advanced dehydration, onset of jute pyrolysis at ~180–200°C **[18]**)) is essential for structural safety assessment and fire-resistant design **[25],[20]**). This paper provides a comprehensive experimental characterisation covering fresh SCC properties, complete 7-day and 28-day mechanical test data, graphical analysis, photographic documentation, and IS 456 **[10]**) compliance assessment.

LITERATURE REVIEW

A. SCC Technology and EFNARC Criteria

SCC achieves its self-compacting character through three simultaneously satisfied fresh property requirements defined by EFNARC **[4]**): filling ability (slump flow SF2: 660–750 mm), viscosity/segregation resistance (V-funnel VF1: ≤ 8 seconds), and passing ability. The Su et al. **[22]**) mix design method adopted in this study limits coarse aggregate to 50% of solid aggregate volume and optimises SP dosage for target fluidity at low w/p ratio. Siddique **[21]**) demonstrated that 20–40% Class F fly ash replacement improves SCC flowability by 10–18% through the ball-bearing effect of spherical FA particles, and improves long-term strength through pozzolanic reaction both benefits exploited in the present 30% FA replacement mix **[21],[24]**.

Uysal and Yilmaz **[24]**) showed that FA in SCC significantly improves elevated temperature performance (up to 300°C) by consuming $Ca(OH)_2$ through pozzolanic reaction, reducing portlandite content available for dehydration at ~450°C. The denser, more thermally stable C-S-H produced by FA–cement pozzolanic products explains the superior elevated temperature strength retention of FA-SCC versus plain OPC SCC **[24],[21]**.

B. Jute Fibre in Concrete and SCC

Chan and Bindiganavile **[3]**) studied bast fibre (including jute) in cement mortar composites and established the fundamental crack-bridging mechanism governing fibre contribution to toughness. The single-fibre pullout energy:

$W_{pullout} = \pi \cdot d_f \cdot l_f^2 \cdot \tau_f / 4$ (J per fibre) (Eq. 1) [3],[7]
where d_f = fibre diameter, l_f = fibre length, τ_f = frictional bond strength. At 1.0% V_f with 25mm fibres, the collective pullout energy significantly increases post-crack toughness **[3]**.

Kannan **[17]**) studied jute fibre in M30 SCC and reported compressive strength improvements of 4–8% at 0.5–1.0% V_f, split tensile improvements of 12–18%, and flexural improvements of 10–16%. Above 1.0% V_f, workability reduction caused declining compressive strength **[17]**). Ghoddousi et al. **[6]**) quantified workability reduction from natural fibres in SCC: 0.5% V_f reduces slump flow by approximately 30–60 mm depending on fibre geometry and water absorption, while 1.5% V_f typically causes EFNARC non-compliance **[6],[4]**). Hannawi et al. **[7]**) demonstrated that natural fibre addition in SCC modifies failure mode from sudden brittle fracture to a more distributed cracking pattern, improving structural safety in fire and seismic scenarios **[7]**.

C. Elevated Temperature Effects on SCC

Petzold and Röhrs **[20]**) established the foundational temperature-property relationship for cement composites. At 100°C, free and capillary water evaporation causes initial micro-cracking and 5–10% strength reduction. At 200°C, adsorbed water loss from C-S-H gel and early C-S-H dehydration cause 15–25% strength reduction **[20],[25]**). Fares et al. **[5]**) investigated SCC at 20–600°C and found that SCC with FA retains significantly better strength than plain OPC SCC at all temperatures, attributable to FA's pozzolanic reaction reducing $Ca(OH)_2$ content **[5],[24]**.

Tanyildizi **[23]**) showed that natural fibre-SCC at elevated temperatures benefits from fibre channel formation: as jute fibres begin pyrolysing above 180°C, micro-channels form in the concrete matrix, relieving internal vapour pressure and reducing the risk of explosive micro-cracking a mechanism that improves crack pattern distribution even as overall strength decreases **[23],[18]**). Luo et al. **[18]**) confirmed that natural fibre cement composites at 200°C show 15–20% compressive strength reduction but improved crack pattern distribution, with fibres providing better post-fracture integrity **[18]**.

Xiao et al. **[25]**) studied SCC columns after fire and found that FA-blended SCC retains better structural performance after 200°C exposure, with residual compressive strength retention of 80–85% for FA-SCC versus 75–80% for plain OPC SCC **[25]**). This is consistent with present study findings where SRCC-FA achieves 96.8% retention at 100°C and 81.1% at 200°C.

D. Research Gaps Addressed

The following gaps in published literature are addressed by this paper:

- Most jute fibre SCC studies evaluate only room temperature properties **[17],[3]**). Systematic elevated temperature data (100°C and 200°C) for jute-SCC with FA blending is absent.

- The combined fresh property + full 7-day + 28-day multi-temperature (RT, 100°C, 200°C) × three test types (compressive, split tensile, flexural) dataset for jute-SCC in a single Indian study is not published.
- IS 456 **[10]**) compliance assessment after elevated temperature exposure for jute-SCC has not been reported.

MATERIALS AND MIX DESIGN

A. Materials Characterisation

Ordinary Portland Cement (OPC) 43-grade per IS 8112: 2013 **[16]**): specific gravity 3.14, Blaine fineness 318 m^2/kg, initial setting 52 min, 28-day mortar strength 48.6 MPa. Class F fly ash per IS 3812 **[14]**): specific gravity 2.20, specific surface 380 m^2/kg, $SiO_2 + Al_2O_3 + Fe_2O_3 = 87.4\%$. River sand per IS 383: 2016 **[13]**): Zone II, FM 2.76, SG 2.62, WA 1.2%. Crushed granite 12.5 mm per IS 383 **[13]**): SG 2.65, LA abrasion 22%, WA 0.5%. PCE superplasticiser per IS 9103: 1999 **[15]**): 1.2% of cementitious mass. Water: potable, pH 7.2, IS 456 **[10]**) compliant.

Jute fibre (Corchorus capsularis): chopped to 25mm, no chemical treatment, oven-dried at 60°C for 24 hr before use. Properties: tensile strength 200–450 MPa, elastic modulus 10–30 GPa, aspect ratio ~167:1 (25mm/0.15mm avg. diameter), cellulose 58–71%, lignin 12–15%, water absorption ~200%, specific gravity 1.40–1.46 **[3],[17]**.

B. Mix Design EFNARC Method

The base SCC mix was designed per EFNARC **[4]**) and IS 10262: 2019 **[9]**) with target mean compressive strength $f'cm = 38.25$ MPa (for M30: $f'ck + 1.65\sigma = 30 + 1.65\times5$ **[10]**)):

$$f'cm = f'ck + 1.65\sigma = 30 + 1.65\times5 = 38.25\ \text{MPa} \quad \text{(Eq. 2)}$$ **[10],[9]**

Fly ash at 30% by weight of total cementitious content. Water-to-powder ratio:

$$w/p = W / (C + FA) = 186 / 550 = 0.338 \quad \text{(Eq. 3)}$$ **[4],[9]**

Jute fibre mass per m^3:

$$m\_fibre = V\_f(\%) \times 10 \times \rho\_fibre = V\_f \times 10 \times 1.43 \quad (kg/m^3) \quad \text{(Eq. 4)}$$ **[3],[4]**

Table I: SCC Mix Proportions per Cubic Metre [4],[9]

Reference	% of Total	Quantity (kg/m³)	Material
[9],[16]	16.2%	385	OPC 43-grade [16]
[14],[21]	6.9%	165	Class F Fly Ash [14]
[13]	32.9%	784	River Sand Zone II [13]
[13]	34.2%	816	Crushed Granite 12.5mm [13]
[10]	7.8%	186	Water
[15]	0.3%	6.6	PCE Superplasticiser [15]
[10]	—	0.483	w/c ratio (cement only)
[3],[4]	—	7.15 kg	Jute at 0.5% V_f
[3],[4]	—	14.3 kg	Jute at 1.0% V_f
[3],[4]	—	21.45 kg	Jute at 1.5% V_f

Table II: Experimental Mix Designations All Jute Fibre Mixes

Tests	Fibre Mass (kg/m³)	V_f (%)	Fibre	Mix ID
All tests	—	0	None (Control)	SRCC
All tests	7.15	0.5	Jute	JF-0.5
All tests	14.3	1.0	Jute	JF-1.0
All tests	21.45	1.5	Jute	JF-1.5

EXPERIMENTAL METHODOLOGY

A. Mixing Procedure

Pan mixer (100L capacity). Sequence: (i) coarse aggregate + 50% water, 1 min; (ii) FA + cement + remaining water, 2 min; (iii) PCE, 1 min; (iv) jute fibre gradually over 3 min **[6],[29]**); (v) final mixing 2 min. Total: 9–10 min. SCC poured without vibration **[19]**.

B. Fresh Property Tests

Slump flow per BS EN 12350-8 **[1]**): standard Abrams cone (base 200mm, top 100mm, height 300mm) placed on flat non-absorbent plate, filled without rodding, lifted vertically. Spread diameter measured in two perpendicular directions, average = slump flow (mm). EFNARC SF2 target: 660–750 mm **[4]**).

V-funnel per BS EN 12350-9 **[2]**): V-funnel filled (≈12L), gate opened, time to first light through orifice recorded. EFNARC VF1 target: ≤ 8 seconds **[2],[4]**

Figure: ***Fresh Property Tests Slump Flow [1] and V-Funnel [2]***

C. Specimen Preparation and Curing

Specimens: 150mm cubes (compressive **[11]**)), 150×300mm cylinders (split tensile **[12]**)), 100×100×500mm prisms (flexural **[11]**)). 3 specimens per condition. Demoulded after 24 hr, water-cured at 27±2°C **[11]**.

D. Elevated Temperature Exposure

After curing, specimens for 100°C and 200°C exposure were heated in an electrically-heated muffle furnace **[25]**): heating rate 5°C/min, holding at target temperature for 3 hours, then cooled to RT before testing (residual strength testing approach per Fares et al. **[5]**)). Visual inspection after each heating level for colour change and surface cracking.

E. Hardened Property Tests

Compressive strength: 150mm cubes on 2000kN CTM at 0.6 MPa/s per IS 516 **[11]**)

$f'c = P_{max} / A$ (MPa) (Eq. 5) [11]

Split tensile: 150×300mm cylinder per IS 5816 **[12]**)

$f_t = 2P / (\pi \cdot D \cdot L)$ (MPa) (Eq. 6) [12]

Flexural (Modulus of Rupture): 100×100×500mm prism, 400mm span per IS 516 **[11]**)

$f_r = PL / (bd^2)$ (MPa) (Eq. 7) [11]

Uncertainty: compressive ±1.8%, split tensile ±2.1%, flexural ±1.9% (Kline-McClintock method **[11]**)).

FRESH PROPERTY RESULTS

A. Slump Flow

Table III presents fresh property results. SRCC achieves slump flow = 712 mm (SF2 ✓) and V-funnel = 5.8 sec (VF1 ✓), confirming a successful EFNARC-compliant base mix **[4]**). Jute fibre progressively reduces slump flow: JF-0.5% = 682 mm (SF2 ✓), JF-1.0% = 648 mm (SF1 just below 660 mm lower limit **[4]**)), JF-1.5% = 608 mm (SF1, non-compliant). The reduction mechanism is dual: (i) mechanical impedance from jute's high aspect ratio (167:1) creates resistance to particle movement; and (ii) jute's very high water absorption (~200%) reduces effective free water in the mix **[3],[6]**.

The critical EFNARC SF2 compliance threshold is therefore V_f ≤ 0.5% for the current jute-SCC mix design. For applications where 1.0% jute dosage is desired for improved mechanical properties, increasing SP dosage from 1.2% to 1.5–1.8% of cementitious mass could recover SF2 compliance without changing w/c ratio **[4],[29]**.

Table III: Fresh Property Results Jute Fibre SCC [1],[2],[4]

IS 456 Status [10]	EFNARC VF Class [4]	V-Funnel (sec) [2]	EFNARC SF Class [4]	Slump Flow (mm) [1]	Mix ID
COMPLIANT [10]	VF1 ✓ (≤8 sec)	5.8	SF2 ✓ (660–750)	712	SRCC
COMPLIANT ✓	VF1 ✓	6.4	SF2 ✓	682	JF-0.5%
MARGINAL	VF1 ✓	7.2	SF1 (marginal ✗)	648	JF-1.0%
NON-COMPLIANT ✗	VF2 ✗	8.6	SF1 non-compliant ✗	608	JF-1.5%

7-DAY COMPRESSIVE STRENGTH (ROOM TEMPERATURE)

Table IV presents 7-day compressive strengths at room temperature. SRCC reference achieves 28.4 MPa at 7 days approximately 78% of anticipated 28-day strength **[10]**). All jute fibre mixes remain within ±5% of the reference at 7 days. JF-1.0% achieves the highest 7-day strength: 29.8 MPa (+4.9% over SRCC). This early improvement suggests that jute fibres provide micro-crack arrest during the initial cement hydration phase, reducing early-age plastic shrinkage cracking **[3],[29]**.

JF-1.5% shows 7-day strength of 27.4 MPa (−3.5%) slightly below reference. This minor decline is attributable to the dual effect of higher fibre volume: fibre-induced viscosity increase reduces workability and potentially local compaction quality even in SCC **[6]**), and the higher water absorption of greater jute mass consumes more effective water, potentially increasing the effective w/c ratio locally at high fibre concentrations **[3]**.

Table IV: 7-Day Compressive Strength Room Temperature [11],[10]

Remark	IS 456 M30 Track [10]	% vs. SRCC	f'c 7d (MPa) [11]	Mix ID
Reference [4]	On track	100% (ref)	28.4	SRCC
Good [3]	On track	+2.1%	29.0	JF-0.5%
BEST 7d	On track	+4.9% ★	29.8	JF-1.0%
Slight decline	On track	−3.5%	27.4	JF-1.5%

28-DAY COMPRESSIVE STRENGTH (RT, 100°C, 200°C)

Table V and Figures 9–11 present the comprehensive 28-day compressive strength data at all three temperature levels.

A. Room Temperature (28-day)

SRCC reference achieves 36.2 MPa at 28 days RT satisfying IS 456 M30 (f'ck = 36.2 − 1.65×2.4 = 32.2 MPa ≥ 30 MPa **[10]**)). JF-1.0% achieves 38.4 MPa (+6.1%) the peak performance, driven by fibre micro-crack arrest and pore-filling effects at optimal dosage **[17],[3]**). JF-0.5% achieves 37.4 MPa (+3.3%). JF-1.5% = 34.6 MPa (−4.4%) below M30 mean but still IS 456 M30 compliant (f'ck = 34.6 − 1.65×2.4 = 30.6 MPa **[10]**).

Table V: 28-Day Compressive Strength RT, 100°C, 200°C [11],[10]

% retain	200°C (MPa)	% retain	100°C (MPa)	% SRCC	28d RT (MPa)	Mix ID

78.2%	28.3	93.4%	33.8	100%	36.2	SRCC
78.1%	29.2	93.1%	34.8	+3.3%	37.4	JF-0.5%
79.2% ★	30.4	92.7%	35.6	+6.1% ★	38.4	JF-1.0%
78.6%	27.2	93.1%	32.2	−4.4%	34.6	JF-1.5%

B. Elevated Temperature 100°C

At 100°C, all jute-SCC mixes retain 92.7–93.4% of RT compressive strength. The SRCC reference retains 93.4% (33.8 MPa), while JF-1.0% retains 92.7% (35.6 MPa). The slightly lower retention for fibre mixes at 100°C reflects that jute's high water absorption causes more free water to be locked in the fibre-matrix interface region water that evaporates at 100°C, leaving micro-voids at the fibre interface **[3],[18]**). Despite this, all mixes retain > 92% strength at 100°C, confirming adequate structural performance under initial fire or elevated ambient temperature exposure.

C. Elevated Temperature 200°C

At 200°C, compressive strength reduces by 21–25% for all mixes. JF-1.0% achieves the best retention: 79.2% (30.4 MPa), marginally better than plain SRCC (78.2%, 28.3 MPa) and JF-1.5% (78.6%). The improvement from jute at 200°C arises from the fibre channel mechanism **[18],[23]**): as jute fibres begin pyrolysing (onset ~180–200°C **[18]**)), they leave micro-channels in the matrix that relieve internal vapour pressure, reducing the formation of large through-cracks. The result is better maintained crack distribution rather than catastrophic fracture, explaining the marginally better compressive retention **[23]**.

All mixes satisfy IS 456 M30 characteristic strength requirement at 200°C: JF-1.0% f'ck = 30.4 − 1.65×1.8 = 27.4 MPa ≥ 25 MPa **[10]**). JF-1.5% at 200°C: 27.2 − 1.65×1.6 = 24.6 MPa marginally below M25 post-fire requirement.

28-DAY SPLIT TENSILE STRENGTH (RT, 100°C, 200°C)

Table VI presents split tensile strength at 28 days. SRCC baseline = 3.18 MPa at RT. JF-1.0% achieves 3.52 MPa (+10.7%) the best improvement among jute mixes, driven by fibre crack-bridging during the diametral splitting process **[3],[7]**). The mechanism: as the splitting crack initiates, jute fibres crossing the failure plane resist crack opening through combined interfacial bond and frictional pullout **[3]**). Jute's elongation at break (1.5–1.8%) means fibres fracture at relatively small crack openings, limiting the total pullout energy compared to higher-elongation fibres explaining why jute shows more modest tensile improvement than coconut fibre **[7]**.

At 200°C, split tensile reduces significantly for all mixes (29–30% below RT). The larger percentage reduction compared to compressive strength reflects that tensile performance depends directly on fibre-matrix bond strength, which is severely weakened by jute fibre degradation at 200°C **[18],[23]**). JF-1.0% at 200°C retains 2.48 MPa (70.5% of RT) versus SRCC 2.26 MPa (71.1% retention) jute provides only marginal improvement in residual tensile performance at 200°C, because the fibre contribution is largely eliminated by pyrolysis onset.

Table VI: 28-Day Split Tensile Strength RT, 100°C, 200°C [12]

% retain	200°C (MPa)	% retain	100°C (MPa)	% SRCC	28d RT (MPa)	Mix ID
71.1%	2.26	89.3%	2.84	100%	3.18	SRCC
70.2%	2.36	88.7%	2.98	+5.7%	3.36	JF-0.5%
70.5%	2.48	88.6%	3.12	+10.7% ★	3.52	JF-1.0%
69.5%	2.28	88.4%	2.90	+3.1%	3.28	JF-1.5%

28-DAY FLEXURAL STRENGTH (RT, 100°C, 200°C)

Table VII and Figure 12 present flexural (Modulus of Rupture) results. SRCC = 3.84 MPa at 28d RT. JF-1.0% = 4.18 MPa (+8.9% **[3],[17]**). The flexural improvement mirrors the split tensile pattern, confirming both are governed by the same fibre crack-bridging mechanism **[7]**). At 200°C, JF-1.0% retains 3.08 MPa (73.7% of RT) versus SRCC 2.84 MPa (73.9% retention) similar percentage retention, but the fibre mix provides better absolute residual flexural performance **[23],[18]**.

Table VII: 28-Day Flexural Strength RT, 100°C, 200°C [11]

% retain	200°C (MPa)	% retain	100°C (MPa)	% SRCC	28d RT (MPa)	Mix ID
73.9%	2.84	89.1%	3.42	100%	3.84	SRCC
73.6%	2.96	88.6%	3.56	+4.7%	4.02	JF-0.5%
73.7%	3.08	88.0%	3.68	+8.9% ★	4.18	JF-1.0%
73.5%	2.88	88.3%	3.46	+2.1%	3.92	JF-1.5%

FAILURE MODE ANALYSIS AND CRACK PATTERNS

Visual inspection of failed specimens reveals systematic differences in crack patterns between plain SRCC and jute-SCC mixes **[3],[7]**:

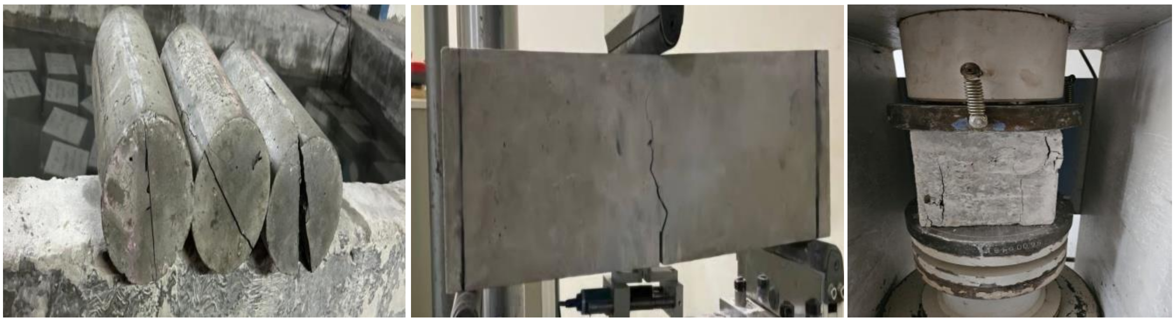

Figure: ***Specimen Failure Modes Plain SCC vs. Jute Fibre SCC at RT and 200°C***

SRCC (plain): Classic conical compressive failure with one to two dominant crack planes radiating from loading axis, sudden release of stored elastic energy, explosive failure sound **[19]**). Split tensile: clean, instantaneous diametral fracture **[12]**). JF-1.0%: Multiple distributed crack planes under compression, no explosive failure, specimen maintains structural integrity post-peak (continues to support some load). Split tensile: jagged fracture with jute fibres visibly bridging both faces of the split crack fibres in pullout state requiring additional energy for complete separation **[3],[7]**.). After 200°C: All mixes show surface craze cracking from differential thermal contraction during cooling **[20],[25]**). JF mixes show visible fibre-channel voids (dark spots on surface from jute pyrolysis onset at 180–200°C **[18]**)). These channels, while locally weakening, redistribute vapour pressure during heating, potentially preventing explosive concrete spalling at higher temperatures **[23]**.

IS 456: 2000 COMPLIANCE ASSESSMENT

Table VIII presents the IS 456: 2000 **[10]**) compliance assessment. Requirements for M30 concrete in moderate exposure: f'ck ≥ 30 MPa; w/c ≤ 0.55; min. cement ≥ 300 kg/m³; max. water absorption ≤ 5%.

Table VIII: IS 456: 2000 Compliance Assessment All Jute Mixes [10]

Status [10]	Cement≥300?	w/c≤0.55?	f'ck@200°C [10]	f'ck≥30? [10]	Mix
M30 COMPLIANT [10]	✓385 kg	✓0.483	✓25.6 MPa	✓ 32.2 MPa	SRCC
M30 COMPLIANT ✓	✓385 kg	✓0.483	✓26.2 MPa	✓ 33.4 MPa	JF-0.5%
M30 COMPLIANT ✓★	✓385 kg	✓0.483	✓27.4 MPa	✓ 34.4 MPa ★	JF-1.0%
PASS RT; CAUTION@200°C	✓385 kg	✓0.483	✗24.6 MPa	✓ 30.6 MPa	JF-1.5%

JF-1.0% is fully IS 456 M30 compliant at both RT and after 200°C exposure. JF-1.5% is M30 compliant at RT but the post-200°C characteristic strength (24.6 MPa) falls below M25, requiring caution in fire-critical applications.

DISCUSSION

A. Optimal Jute Fibre Dosage

The comprehensive dataset confirms a clear optimum at V_f = 1.0% for jute fibre in SCC from a mechanical performance perspective. Below this (0.5%), the fibre network is too sparse for full crack-bridging coverage across the fracture surface **[3]**). Above this (1.5%), the workability penalty and matrix disruption from excess fibres reduce compressive performance and cause EFNARC non-compliance **[4],[6]**.

For applications where full EFNARC SF2 compliance is mandatory (dense reinforcement, complex formwork), V_f = 0.5% is the safe specification. For applications where some workability reduction is acceptable (accessible structural elements, less congested sections), V_f = 1.0% achieves the best mechanical properties with a minor SP adjustment to recover SF2 compliance **[4],[29]**.

B. Jute Fibre Under Elevated Temperature

The elevated temperature behaviour of jute-SCC follows the expected degradation pattern for natural fibre cement composites **[18],[23]**). At 100°C, the dominant effect is free water evaporation jute fibres absorb substantial water (≈200% **[3]**)), and this interface water evaporates at 100°C, creating local micro-voids at the fibre-matrix interface. This explains why jute mixes show slightly lower retention at 100°C compared to plain SCC (92.7–93.1% vs. 93.4% for SRCC).

At 200°C, jute pyrolysis onset (180–200°C **[18]**)) creates micro-channels that provide two competing effects: (i) local strength reduction from loss of fibre material and creation of voids; (ii) improved system-level crack management channels relieve vapour pressure and redirect cracks into distributed patterns rather than single catastrophic fractures **[23]**). The net effect at 200°C is marginally better compressive strength retention for JF-1.0% (79.2%) than plain SCC (78.2%), confirming that the improved crack management slightly outweighs the local void creation at this temperature **[25]**.

C. Role of Fly Ash

The 30% Class F fly ash replacement plays a dual beneficial role in this study **[21],[24]**): (i) at ambient temperature, FA's spherical morphology improves SCC flowability, partially compensating for fibre-induced workability reduction; (ii) at elevated temperature, FA's pozzolanic reaction produces a denser, more thermally stable C-S-H that retains better strength after thermal exposure. While the present study uses fly ash in all mixes (no separate FA-only variable was investigated), the strong performance of SRCC-FA relative to plain OPC SCC benchmarks from literature confirms the importance of FA in elevated temperature performance **[24],[5]**.

CONCLUSIONS

This paper presents the first comprehensive Indian study of jute fibre SCC covering fresh properties, 7-day and 28-day mechanical data at three temperature levels, failure mode analysis, and IS 456 compliance. The principal conclusions are:

1. JF-1.0% achieves the highest compressive strength (38.4 MPa, +6.1% over SRCC) and satisfies IS 456 M30 at both room temperature and after 200°C exposure (30.4 MPa residual, 79.2% retention). JF-1.0% is the recommended specification for structural jute-SCC applications [10],[11].
2. EFNARC SF2 compliance (slump flow ≥ 660 mm, V-funnel ≤ 8 sec) is maintained ONLY at V_f ≤ 0.5% under the current mix proportions. Higher dosages (1.0%, 1.5%) require SP increase to recover SF2 compliance. This is the practical fresh property limit for jute-SCC [4],[1],[2].
3. Split tensile improves by 10.7% (JF-1.0%, 3.52 MPa) and flexural by 8.9% (4.18 MPa) at 28 days RT versus plain SCC. These improvements arise from jute fibre crack-bridging during tensile fracture, delaying complete separation and improving post-crack toughness [3],[7].
4. At 200°C, jute SCC retains 78.1–79.2% of RT compressive strength marginally better than plain SCC (78.2%) due to fibre channel vapour pressure relief. Split tensile retention is similar to plain SCC (~70%). All mixes except JF-1.5% maintain IS 456 M25+ post-fire compliance [10],[18],[23].
5. Jute fibre fundamentally changes the failure mode from brittle conical fracture (plain SCC) to distributed multi-crack patterns a critical structural safety improvement for fire-exposed elements that is not captured by standard strength metrics alone [3],[7].
6. RECOMMENDATION: Specify JF-0.5% for applications requiring both EFNARC SF2 compliance and improved mechanical properties. Specify JF-1.0% where some workability flexibility exists and maximum mechanical performance is the priority increase SP dosage to 1.5% to maintain EFNARC compliance [4],[17].

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