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Mechanical Characterisation of Fibre-Reinforced Concrete Using Cyperus Tegetum (Madur Kathi) Natural Fibres

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Abstract: Conventional concrete performs well in compression but remains vulnerable to tensile cracking and brittle failure. Discrete fibres can bridge developing cracks and improve the tensile and flexural response of the cementitious matrix. This study experimentally evaluates *Cyperus tegetum* (locally known as Madur Kathi), a renewable mat-sedge traditionally cultivated in parts of West Bengal, as a natural fibre additive in M25 and M30 concrete. Fibre contents of 0%, 0.5%, 1.0% and 1.5% by weight of cement were investigated. Fresh-concrete workability was assessed by slump testing, while compressive, split tensile and flexural strengths were measured after 7 and 28 days of water curing. The reported results identify 1.0% fibre content as the best-performing dosage among those tested. At this dosage, the thesis reports approximate improvements of 4% in compressive strength, 8% in split tensile strength and 9% in flexural strength relative to the control mix. Slump decreased as fibre content increased, and the 1.5% mixes showed reduced strength, attributed to fibre clustering, entrapped voids and poorer compaction. The findings indicate potential for *Cyperus tegetum* as a locally available reinforcement additive, while longer-term durability and microstructural validation remain necessary before structural adoption.

Keywords: fibre-reinforced concrete; *Cyperus tegetum*; Madur Kathi; natural fibre; compressive strength; split tensile strength; flexural strength; sustainable construction.

I. INTRODUCTION

Concrete is widely used because its ingredients are readily available and it offers high compressive strength. However, its relatively low tensile capacity and brittle post-cracking behaviour can limit performance under tensile and flexural loading. Fibre-reinforced concrete incorporates short, discrete fibres into the matrix to help control crack development, transfer stress across cracks and improve toughness. Steel and synthetic fibres are established options, but their cost, production energy, corrosion susceptibility in some environments have encouraged interest in renewable plant-based alternatives.

Cyperus tegetum, commonly known as Madur Kathi in West Bengal and treated in this thesis as associated with *Cyperus pangorei*, is a mat-sedge whose slender culms are traditionally used for manufacturing mats. It is cultivated and utilized in several parts of West Bengal, particularly in Paschim Medinipur, Purba Medinipur, and certain areas of North 24 Parganas. Its local availability and established processing tradition make it a candidate for investigation as a natural fibre additive. Natural fibres, however, can absorb water and may be vulnerable to the alkaline pore solution of cement; their geometry, dispersion and dosage therefore require control.

The lack of experimental data on *Cyperus tegetum* in concrete, specifically with regard to compressive, split tensile, and flexural performance, is the specific research need. The present work compares control concrete with M25 and M30 mixes containing three fibre dosages and identifies the dosage that balances strength and workability.

II. OBJECTIVES OF THE STUDY

This research aimed to develop and evaluate fibre-reinforced concrete using *Cyperus tegetum* natural fibres by studying its mechanical strength, and suitability for sustainable construction. Based on this, four research objectives were developed which are listed in the section below.

- 1) To develop concrete mixes incorporating *Cyperus tegetum* natural fibres.
- 2) To evaluate the mechanical performance of the developed concrete in terms of compressive strength, split tensile strength and flexural strength of developed concrete.

- 3) To determine the strength optimisation of fibre dosage
- 4) Cost variation if any.

III. MATERIALS AND EXPERIMENTAL METHODOLOGY

The investigation used Ordinary Portland Cement (OPC) 43 grade, fine aggregate, 10 mm and 20 mm coarse aggregates, potable water, chemical admixture and Cyperus tegetum fibres collected from Purba Medinipur, West Bengal. The thesis reports a 70:30 blend of 20 mm and 10 mm coarse aggregate. M25 and M30 control mixes were designed following IS 10262:2019. The fibre contents were 0%, 0.5%, 1.0% and 1.5% by weight of cement; the control mix contained no fibre.

The raw fibres were cleaned to remove dust and surface impurities, dried and cut to short lengths of approximately 2–4 mm. The thesis describes surface treatment, including mild alkali soaking, as a measure intended to remove surface waxes/resins and improve mechanical interlocking. Aggregates were dry-mixed, followed by cement and fibres; water and admixture were then added in stages. Mixing was continued to obtain a visually uniform mix. Fresh concrete was assessed using a slump cone. Cubes measuring 150 × 150 × 150 mm were cast for compressive strength, cylinders measuring 150 × 300 mm for split tensile strength, and beams/prisms measuring 100 × 100 × 500 mm for flexural strength. Specimens were demoulded after approximately 24 hours and water-cured for 7 and 28 days. The thesis reports testing in accordance with relevant Indian Standards, including IS 1199 for fresh concrete, IS 516 for compressive strength and split tensile strength.

Compressive strength was calculated as the maximum failure load divided by the loaded area. Split tensile strength was calculated using $f_t = 2P / \pi LD$, where P is the maximum load, L is cylinder length and D is cylinder diameter. Flexural strength was calculated from the failure load, span and specimen dimensions using the expression : $f_b = \frac{PL}{bd^2}$. The results for each fibre content were compared with the corresponding control mix at each curing age. The reported strength values are averages of three specimens.

IV. RESULTS AND DISCUSSION

The test results for M25 and M30 grades of Control mix concrete with fiber inclusion of 0.5%, 1%, and 1.5% by cement weight are shown in the bar chart and table below.

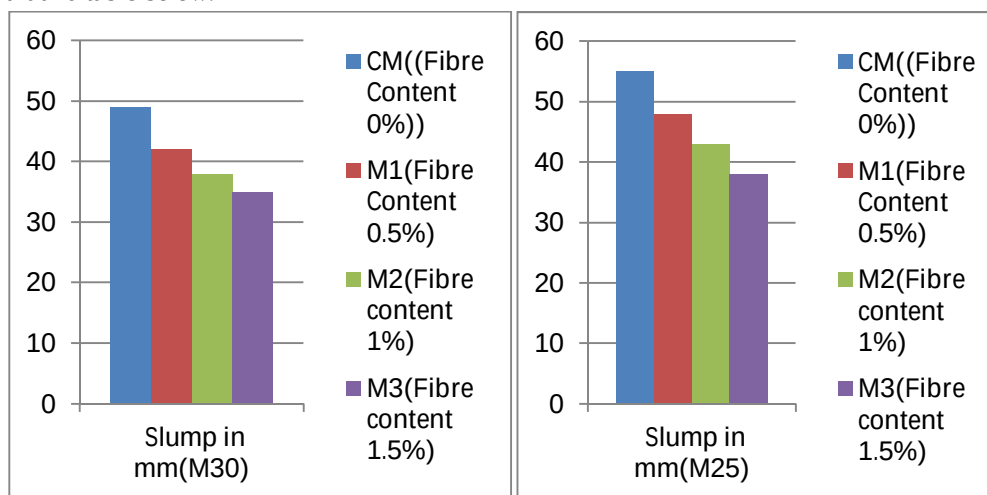


Figure 1: Variation of slump values for M25 and M30 concrete

Table I

Slump values of M25 and M30 concrete mixes

Fibre content by cement weight	M25 slump (mm)	M30 slump (mm)
0% (Control Mix)	55	49
0.5%	48	42
1.0%	43	38
1.5%	38	35

The finding is that increasing Cyperus tegetum fibre content from 0% to 1.5% reduced slump by approximately 29–31% in both concrete grades, demonstrating a consistent trade-off between natural fibre incorporation and fresh-concrete workability.

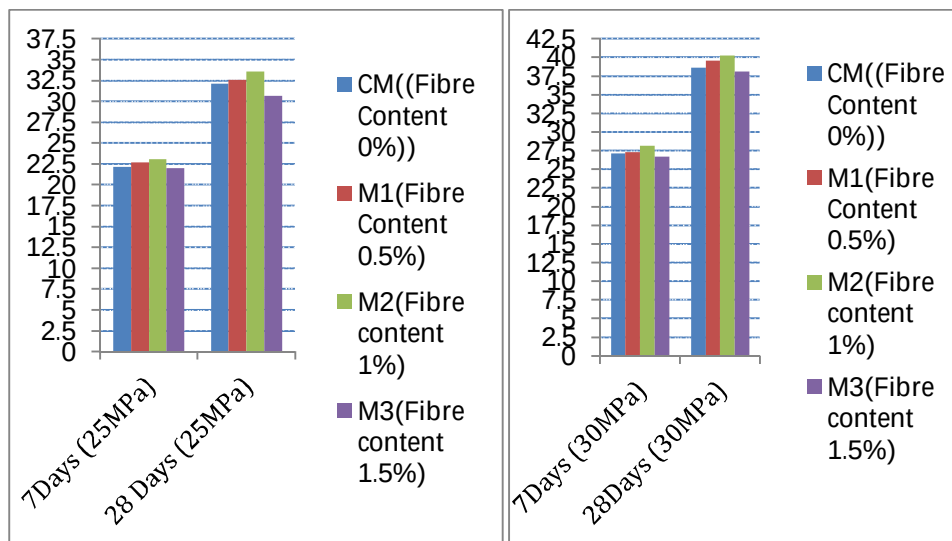


Figure 2: Compressive strength of M25 and M30 concrete

Table II
Compressive Strength Results of M25 and M30 concrete

.Mix	Fibre (%)	M25, 7 days (MPa)	M25, 28 days (MPa)	M30, 7 days (MPa)	M30, 28 days (MPa)
Control	0	22.15	32.08	27.12	38.61
M1	0.5	22.67	32.60	27.32	39.61
M2	1.0	23.10	33.55	28.15	40.28
M3	1.5	22.03	30.66	26.67	38.10

Compressive strength increased at 0.5% and 1.0% fibre contents and reached its maximum at 1.0% for both grades and curing ages for both concret mix.

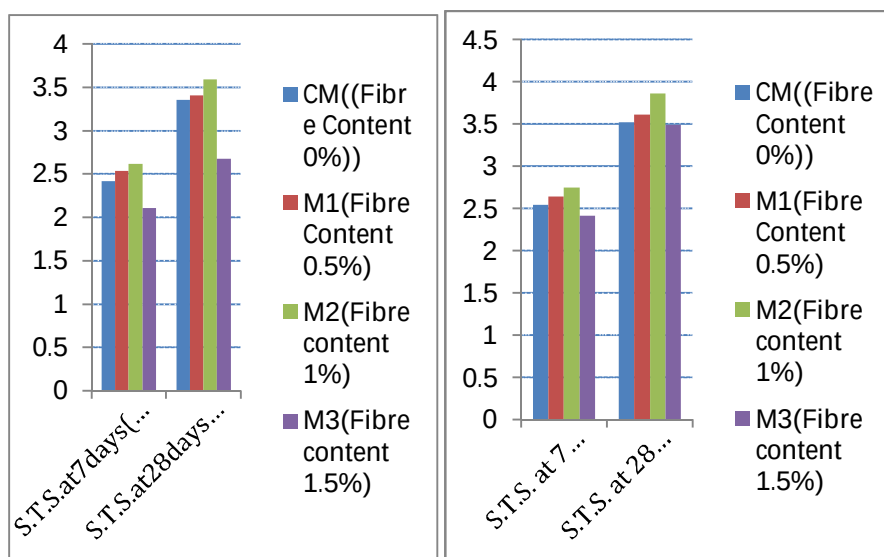


Figure 3: Split tensile strength of M25 and M30 concrete

Table III:
Split tensile strength of M25 and M30 concrete

Mix	Fibre (%)	M25, 7 days (MPa)	M25, 28 days (MPa)	M30, 7 days (MPa)	M30, 28 days (MPa)
Control	0	2.42	3.33	2.54	3.52
M1	0.5	2.54	3.41	2.64	3.61
M2	1.0	2.62	3.59	2.75	3.86
M3	1.5	2.11	2.68	2.41	3.49

The split tensile results followed a similar dosage trend, with the maximum reported value at 1.0% fibre content for both concrete mix.

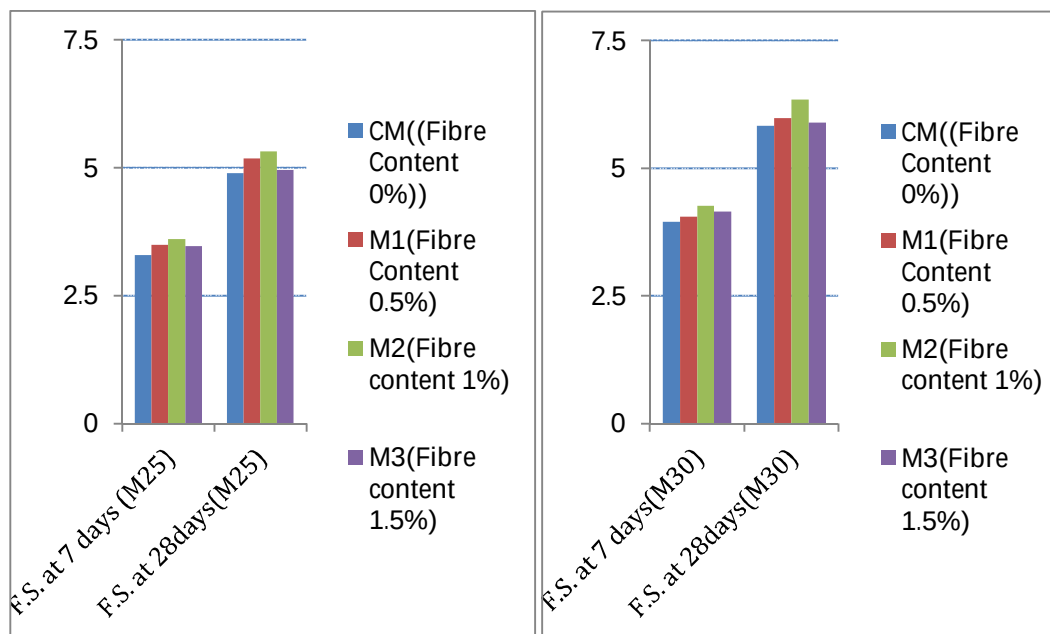


Figure.4. Flexural strength of M25 and M30 concrete

Table IV.
Flexural strength of M25 and M30 concrete

Mix	Fibre (%)	M25, 7 days (MPa)	M25, 28 days (MPa)	M30, 7 days (MPa)	M30, 28 days (MPa)
Control Mix	0	3.30	4.90	3.95	5.83
M1	0.5	3.49	5.18	4.05	5.98
M2	1.0	3.61	5.32	4.26	6.35
M3	1.5	3.47	4.96	4.15	5.90

Flexural strength also peaked at 1.0% fibre content for both concrete mix.

V. DISCUSSION

Across all three strength measures, 1.0% by weight of cement was the best-performing dosage among the tested mixtures. The results indicate that a moderate fibre addition can improve strength, whereas an excessive amount may impair mixing and compaction. The slump results reinforce this trade-off: increasing fibre content reduced workability in both grades. The data do not establish that the fibres can replace conventional steel reinforcement in structural members; rather, they demonstrate the potential of this fibre as a concrete additive for improved mechanical response.

VI. CONCLUSIONS

- 1) *Cyperus tegetum* (Madur Kathi) fibres were incorporated into M25 and M30 concrete at 0.5%, 1.0% and 1.5% by cement weight and compared with fibre-free control mixes.
- 2) The optimum dosage within the tested range was 1.0%. At 28 days, the tabulated results show M25 compressive strength of 33.55 MPa and M30 compressive strength of 40.28 MPa at this dosage.
- 3) At 1.0% fibre content, split tensile strength reached 3.59 MPa for M25 and 3.86 MPa for M30, while flexural strength reached 5.32 MPa and 6.35 MPa, respectively.
- 4) Slump decreased as fibre dosage increased. The 1.5% mixes showed lower strength than the 1.0% mixes, plausibly due to fibre balling, void formation and poorer compaction.
- 5) Locally available Madur Kathi has potential as a sustainable natural fibre additive, but the evidence in this study is limited to short-term laboratory strength and slump testing.

VII. LIMITATIONS

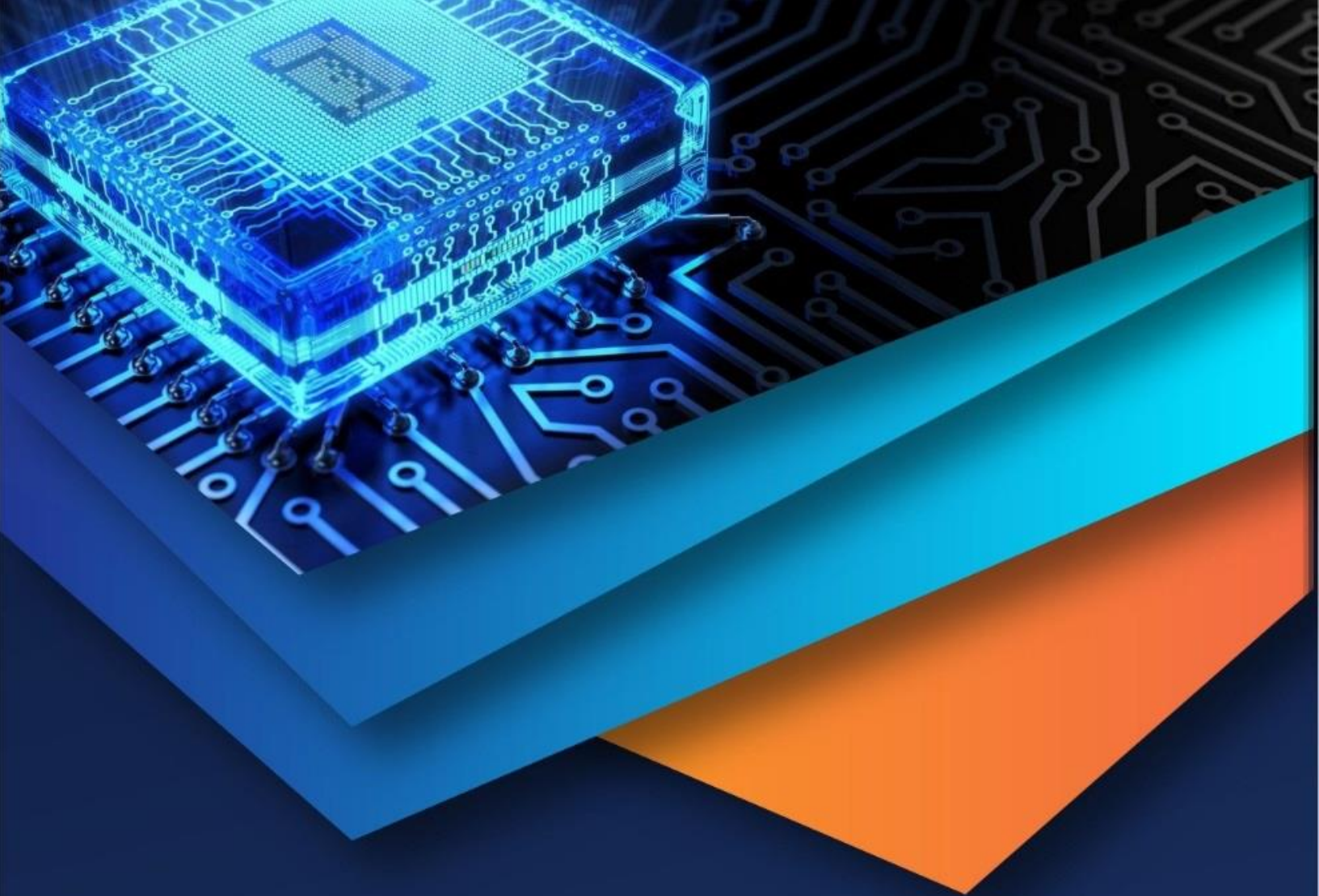
The investigation was limited to 7- and 28-day curing periods, a single short fibre-length range (approximately 2–4 mm), and macro-mechanical tests. Long-term alkaline degradation and resistance to wetting–drying cycles were not evaluated. Water permeability, chloride ingress, carbonation, fibre–matrix interfacial structure, and life-cycle costs were also not established. Consequently, the findings are limited to the mechanical performance observed under the tested conditions, and the long-term durability of *Cyperus tegetum* fibre-reinforced concrete remains to be verified.

VIII. FUTURE WORK

Future research should compare different fibre lengths and fibre-treatment methods to determine their effects on workability and mechanical performance. Durability studies should be extended to longer curing periods and include tests for alkaline degradation, wetting–drying resistance, water permeability, chloride ingress, and carbonation. Scanning Electron Microscopy (SEM), Energy-Dispersive X-ray Spectroscopy (EDS), or related techniques should be used to investigate the fibre–matrix interfacial transition zone. Further studies should also establish the reproducibility of the results and conduct a formal cost and life-cycle assessment. Wider structural applications should be considered only after consistent mechanical performance and adequate durability have been demonstrated.

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