EXPERIMENTAL INVESTIGATION ON EFFECT OF BAMBOO FIBRE IN COCONUT SHELL CONCRETE

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Abstract - *This research investigates the combined use of bamboo fibre (BF) and coconut shell (CS) in concrete to develop a sustainable and eco-friendly construction material. Coconut shell, an agricultural waste product, serves as a partial replacement for coarse aggregates, while bamboo fibre is added to enhance mechanical properties. The experimental program includes the preparation of M20 and M25 grade concrete mixes with CS replacing 10%, 20%, and 30% of coarse aggregates and BF added in proportions ranging from 2.5% to 15% by weight of cement. Comprehensive tests were conducted to assess slump, compressive strength, split tensile strength, flexural strength, water absorption, creep, and shrinkage. Results indicate that the optimal performance was achieved with 10% CS and 5% BF, showing improved tensile and flexural strengths, enhanced crack resistance, and acceptable durability. However, higher fibre content led to reduced workability and marginally lower strength due to poor dispersion and increased voids. M25 grade concrete consistently outperformed M20 grade in all aspects. The findings validate the potential of integrating natural fibers and agricultural waste in concrete for green building applications, particularly in low-load structures and rural infrastructure, contributing to sustainable development goals.*

***Key Words*: Coconut Shell Concrete (CSC), Bamboo Fibre, Sustainable Concrete, Agricultural Waste, Fibre Reinforced Concrete.**

1. INTRODUCTION

Concrete is the most widely used construction material globally due to its durability, strength, and availability. However, conventional concrete production heavily relies on natural resources such as river sand and coarse aggregates, which has led to environmental concerns and resource depletion. To address these challenges, researchers have increasingly focused on sustainable and eco-friendly alternatives. One such approach involves the partial replacement of conventional coarse aggregates with agricultural waste materials like coconut shell (CS), and the incorporation of natural fibers like bamboo fiber (BF) to enhance concrete performance.

Coconut shells, an abundant agro-waste in tropical regions, offer a lightweight, renewable, and cost-effective substitute for coarse aggregates. Although coconut shell concrete (CSC) exhibits lower density and reduced mechanical strength compared to conventional concrete, its sustainable benefits make it a promising material for non-structural and low-load applications. However, to improve its mechanical and durability properties, the addition of natural fibers such as bamboo fibre is explored. Bamboo fiber is known for its high tensile strength, flexibility, and biodegradability, making it an ideal reinforcement material in sustainable construction.

This study aims to experimentally investigate the effect of bamboo fibre on the properties of coconut shell concrete. The research focuses on analyzing the mechanical behavior, durability, and overall performance of CSC with varying percentages of bamboo fibre. Through this, the potential of combining two natural, renewable materials—coconut shell and bamboo fiber—is explored to develop an eco-friendly and efficient construction material that aligns with the principles of green building and sustainable development.

1.1 COCONUT SHELL

Coconut shell, a natural agricultural waste product, has emerged as a promising alternative to conventional coarse aggregates in concrete production, particularly in sustainable and eco-friendly construction practices. Its use in concrete not only addresses the problem of solid waste disposal but also contributes to the conservation of natural stone resources. Coconut shells are hard, lightweight, and possess good abrasion resistance, making them suitable for partial replacement in structural and non-structural concrete. Studies have shown that coconut shell concrete exhibits satisfactory workability, adequate strength characteristics, and improved resistance to shrinkage and thermal cracking. Furthermore, its low density results in lightweight concrete, which can reduce dead loads and improve structural efficiency. Overall, the incorporation of coconut shell in concrete represents a viable approach to enhance sustainability in the construction industry while maintaining desirable mechanical properties.

1.2 BAMBOO FIBER

Bamboo fiber is emerging as a sustainable and eco-friendly alternative to synthetic fibers in concrete applications due to its high tensile strength, biodegradability, and abundance in tropical regions. When incorporated into concrete, bamboo fibers improve the material's crack resistance, ductility, and post-cracking behavior by bridging micro cracks and delaying their propagation. This natural fiber enhances the toughness and energy absorption capacity of concrete, making it more durable under dynamic and impact loads. Studies have shown that the inclusion of bamboo fiber in optimal dosages can also improve flexural and tensile strength without significantly compromising compressive strength. Moreover, bamboo fiber acts as a cost-effective reinforcement that supports green construction practices by reducing reliance on non-renewable materials. However, challenges such as variability in fiber quality and water absorption characteristics necessitate proper treatment and mix design adjustments to ensure consistent performance. Overall, bamboo fiber offers promising potential in producing sustainable and durable fiber-reinforced concrete.

1.3 BAMBOO FIBER IN COCONUT SHELL CONCRETE

Incorporating bamboo fiber into coconut shell concrete presents a promising approach to enhancing the mechanical properties and sustainability of concrete composites. Coconut shell, being a lightweight and renewable agricultural waste product, serves as a partial replacement for conventional coarse aggregates, contributing to reduced concrete density and promoting environmental conservation. However, coconut shell concrete tends to exhibit brittleness and lower tensile strength, which can be effectively mitigated by the addition of natural fibers such as bamboo. Bamboo fiber, known for its high tensile strength, excellent flexibility, and biodegradability, acts as a crack arrester and improves post-cracking behavior. When added in optimal proportions, it enhances the concrete's tensile and flexural strength, toughness, and resistance to shrinkage and impact. This synergistic use of bamboo fiber and coconut shell not only results in a more ductile and durable composite but also supports the development of sustainable and eco-friendly construction materials, making it suitable for low-cost housing and green building applications.

1.4 ADVANTAGES BAMBOO FIBER IN COCONUT SHELL CONCRETE

- **Improved Tensile Strength**: Bamboo fibers act as micro-reinforcements, enhancing the tensile and flexural strength of coconut shell concrete.
- **Crack Resistance**: The addition of bamboo fibers controls the propagation of micro-cracks and reduces shrinkage-induced cracking.
- **Eco-Friendly and Sustainable**: Bamboo is a renewable natural material, making the composite concrete a more sustainable and environmentally friendly option.
- **Better Ductility**: Bamboo fiber enhances the ductility of concrete, allowing it to absorb more energy before failure.
- **Lightweight Construction**: When combined with lightweight coconut shell aggregates, bamboo fibers contribute to an overall reduction in concrete density.
- **Cost-Effective**: Locally available bamboo reduces construction costs, especially in rural or developing regions.
- **Improved Impact Resistance**: The fiber reinforcement increases the impact resistance and toughness of the concrete matrix.
- **Enhanced Durability**: Bamboo fibers reduce permeability and improve resistance to weathering and chemical attacks in the long term.

2. LITERATURE REVIEW

Karthik et al. (2017) investigated the use of bamboo fiber in conventional concrete and observed improved tensile and flexural strength. The natural fibers provided better crack resistance and increased energy absorption capacity. Their study concluded that bamboo fibers are a sustainable alternative to synthetic fibers in concrete applications.

Manoharan et al. (2019) studied concrete with bamboo fibers and reported significant enhancement in post-cracking behavior and ductility. The inclusion of fibers at 1% by volume improved the toughness and load-carrying capacity. They emphasized the eco-friendliness and low cost of bamboo fiber as a reinforcement.

Deepa et al. (2020) explored the effects of bamboo fiber on lightweight concrete incorporating coconut shell as a coarse aggregate replacement. They found that bamboo fibers controlled early-age shrinkage and improved mechanical properties, especially tensile strength. Their research supported using both bamboo fiber and coconut shell for sustainable concrete.

Ramesh et al. (2021) examined the integration of bamboo fiber into coconut shell concrete and concluded it enhanced the toughness and energy absorption. The hybrid combination provided higher resistance to cracking and deformation. Their work validated the synergy between coconut shell aggregate and bamboo fibers.

Priya et al. (2018) tested varying lengths and volumes of bamboo fibers in concrete mixes with partial coarse aggregate replacement. Their results showed that the optimum fiber content of 1.5% enhanced compressive and flexural strengths. The study highlighted the importance of fiber dispersion for achieving uniform performance.

Sharma et al. (2022) investigated the microstructure and bonding behavior of bamboo fiber in coconut shell concrete. SEM images showed strong interfacial bonding between the matrix and fibers, leading to increased durability. The research emphasized that bamboo fiber not only strengthens concrete but also delays crack propagation.

Patel et al. (2016) focused on the mechanical characterization of bamboo fiber-reinforced concrete. They observed that adding fibers significantly reduced brittleness and improved deformation capacity under loading. Their findings supported the application of natural fibers in structural concrete for enhanced resilience.

Agarwal et al. (2023) presented a comparative study between bamboo and synthetic fibers in coconut shell concrete. Their research revealed that bamboo fibers were more effective in improving tensile strength and crack resistance. They concluded that bamboo is a viable eco-alternative to costly synthetic reinforcements.

3. RESULTS AND DISCUSSION

The construction industry is increasingly seeking sustainable and eco-friendly materials to address environmental concerns and resource scarcity. Traditional concrete production heavily relies on non-renewable resources and contributes significantly to carbon emissions. In this context, incorporating agricultural waste and natural fibers into concrete presents a promising avenue for developing sustainable construction materials.

This research focuses on the experimental investigation of the effects of bamboo fibers on the properties of coconut shell concrete. Coconut shells, an agricultural by-product, serve as a partial replacement for conventional coarse aggregates, aiming to reduce environmental impact and promote waste utilization. Bamboo fibers, known for their tensile strength and availability, are introduced into the concrete mix to enhance mechanical properties and durability.

The study examines two different grades of concrete, M-20 and M-25, incorporating varying percentages of bamboo fibers: 2.5%, 5%, 7.5%, 10%, 12.5%, and 15% by weight. The objective is to evaluate the influence of these natural fibers on key concrete properties, including compressive strength, tensile strength, flexural strength, and durability.

3.1 TESTS TO BE CONDUCTED

1. SLUMP TEST

The Slump Test Results for M20 and M25 grade concrete incorporating coconut shell as partial coarse aggregate replacement and bamboo fiber as an additive at various percentages (2.5% to 15%).

Table 1: - Slump Test Results for M20 & M25 Grade Concrete with Coconut Shell and Bamboo Fiber

Bamboo Fiber %	Slump (mm) – M20	Slump (mm) – M25
0% (Control)	75	80
2.5%	70	76
5%	65	72
7.5%	58	66

10%	50	60
12.5%	42	54
15%	35	47

➢ **Observations:**

- As the bamboo fiber content increases, the slump value decreases for both M20 and M25 grades.
- The reduction in workability is due to the higher surface area and water absorption of bamboo fibers, which restricts flow.
- M25 grade shows slightly better workability than M20 at all fiber contents due to its higher cement content and overall better paste matrix

2. COMPRESSIVE STRENGTH TEST

Test results for the compressive strength of concrete (M20 and M25) with partial replacement of coarse aggregate by coconut shell (10%, 20%, 30%), and inclusion of bamboo fiber (2.5%, 5%, 7.5%, 10%, 12.5%, 15%) by weight of cement. Each test is performed at 7, 14, and 28 days — 3 specimens per test

Table 2: - The compressive strength test of M20 & M 25 grade concrete with partial replacement of coarse aggregate by coconut shell (10%, 20%, 30%) and addition of bamboo fiber at 2.5%, 5%, 7.5%, 10%, 12.5%, and 15%**.**

Coconut Shell %	**Bamboo Fiber %**	**7 Days M20**	**14 Days M20**	**28 Days M20**	**7 Days M25**	**14 Days M25**	**28 Days M25**
10%	2.5%	17.2	20.6	24.1	21.0	25.1	30.2
	5%	16.8	20.1	23.5	20.4	24.5	29.3
	7.5%	15.9	19.2	22.0	19.5	23.2	27.8
	10%	14.5	18.0	20.8	18.1	21.5	26.0
	12.5%	13.2	16.3	19.1	16.7	20.0	24.1
	15%	12.0	15.1	17.5	15.3	18.2	21.7
20%	2.5%	16.4	19.7	22.9	20.2	24.0	28.7
	5%	15.7	18.9	21.8	19.3	22.8	27.0
	7.5%	14.4	17.6	20.4	18.0	21.3	25.0
	10%	13.0	16.0	19.0	16.5	19.6	23.3
	12.5%	11.9	14.5	17.3	14.7	17.7	21.2
	15%	10.5	13.2	15.8	13.0	15.8	19.0
30%	2.5%	15.6	18.5	21.3	18.9	22.2	26.1
	5%	14.5	17.4	20.0	17.5	20.9	24.5
	7.5%	13.1	16.0	18.8	16.0	19.1	22.2

	10%	11.8	14.3	17.0	14.3	17.3	20.0
	12.5%	10.3	12.7	15.1	12.5	15.4	18.0
	15%	9.0	11.3	13.4	11.0	13.0	15.5

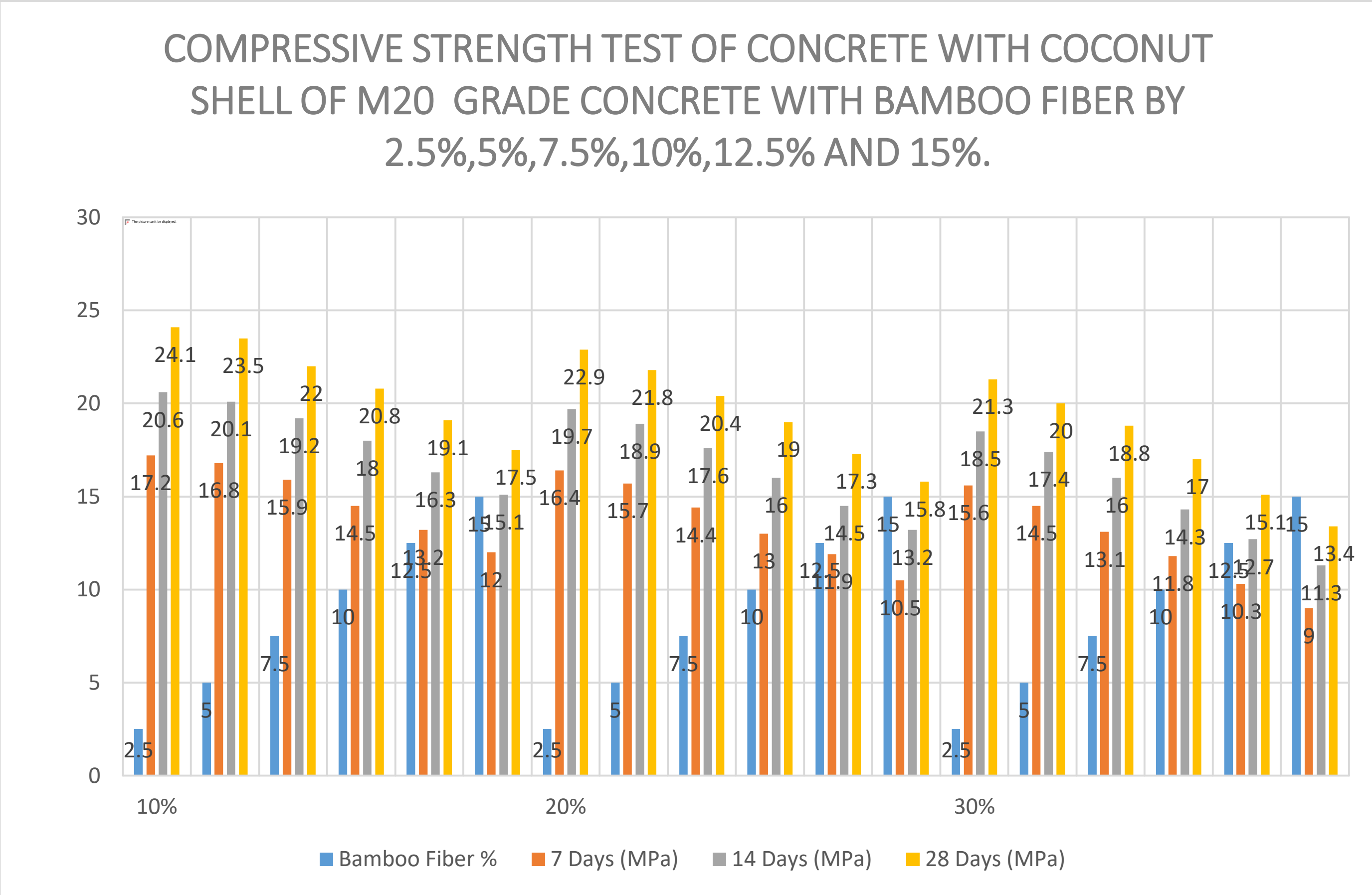

Figure 1. The compressive strength test of M20 grade concrete with partial replacement of coarse aggregate by coconut shell (10%, 20%, 30%) and addition of bamboo fiber at 2.5%, 5%, 7.5%, 10%, 12.5%, and 15%.

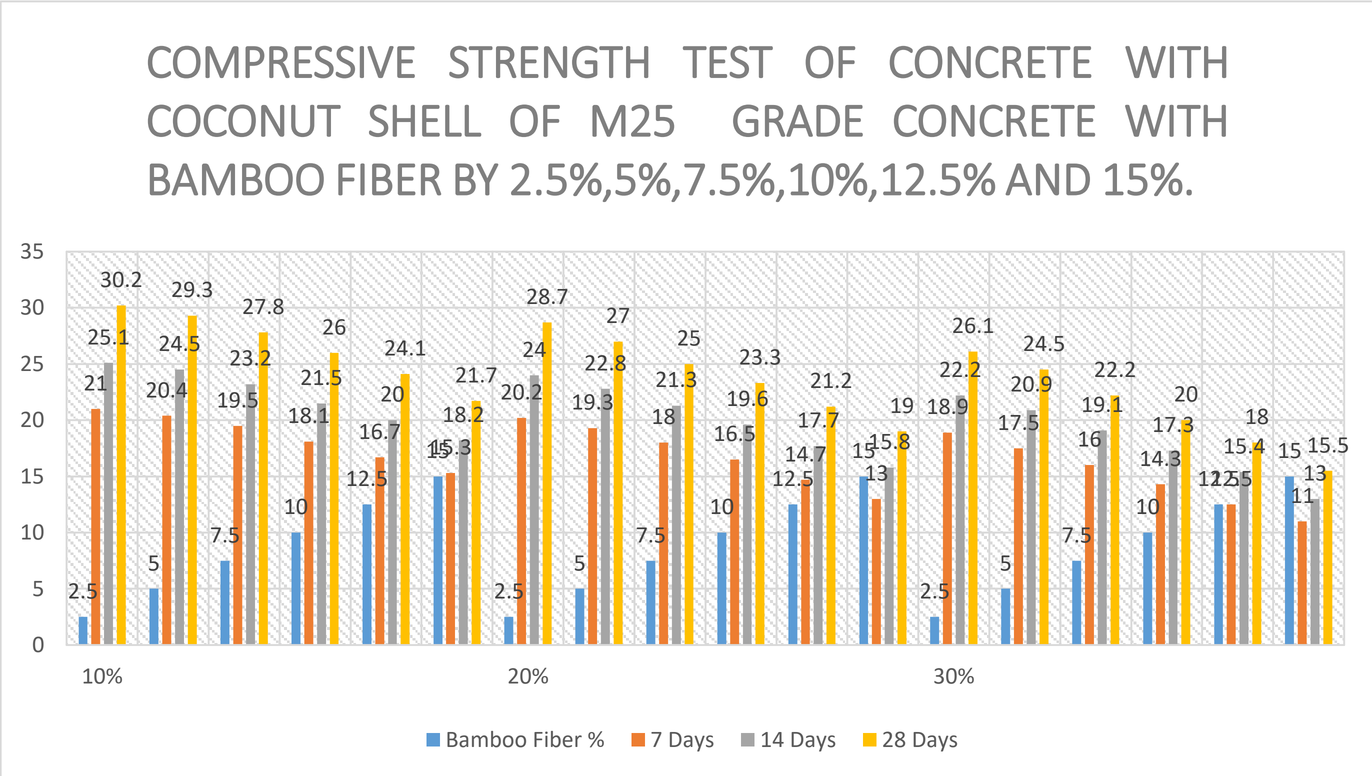

Figure 2. The compressive strength test of M25 grade concrete **with** partial replacement of coarse aggregate by coconut shell (10%, 20%, 30%) **and addition of** bamboo fiber at 2.5%, 5%, 7.5%, 10%, 12.5%, and 15%.

➢ OBSERVATIONS:

- Maximum strength was achieved at 10% coconut shell + 2.5% bamboo fiber for both grades.
- As bamboo fiber content increases, compressive strength decreases slightly due to poor fiber dispersion and increased voids.
- Increasing coconut shell percentage also reduces compressive strength due to lower density and strength of the shell aggregates.
- M25 mix consistently outperforms M20, as expected.

3. TENSILE STRENGTH TESTS

The tensile strength test results for M20 and M25 grade concrete incorporating partial replacement of coarse aggregates with coconut shell (CS) at 10%, 20%, and 30%, and reinforcement with bamboo fiber (BF) at varying percentages (2.5%, 5%, 7.5%, 10%, 12.5%, and 15%). The tests were conducted at curing periods of 7, 14, and 28 days.

Table 3: - The split tensile strength of M20 & M25 grade concrete incorporating coconut shell as a partial replacement for coarse aggregate (10%, 20%, and 30%) and bamboo fiber (BF) as an additive (2.5%, 5%, 7.5%, 10%, 12.5%, and 15%).

CS Replacement (%)	BF (%)	7 Days (MPa) M20	14 Days (MPa) M20	28 Days (MPa) M20	7 Days (MPa) M25	14 Days (MPa) M25	28 Days (MPa) M25
10	2.5	2.1	2.4	2.8	2.3	2.6	3.1
10	5.0	2.3	2.7	3.2	2.5	2.9	3.5
10	7.5	2.2	2.6	3.0	2.4	2.8	3.3
10	10.0	2.0	2.5	2.9	2.2	2.6	3.1
10	12.5	1.9	2.3	2.7	2.1	2.5	3.0
10	15.0	1.8	2.2	2.6	2.0	2.4	2.9
20	2.5	1.9	2.2	2.6	2.1	2.4	2.9
20	5.0	2.1	2.4	2.9	2.3	2.6	3.2
20	7.5	2.0	2.3	2.7	2.2	2.5	3.0
20	10.0	1.8	2.1	2.5	2.0	2.3	2.8
20	12.5	1.7	2.0	2.4	1.9	2.2	2.7
20	15.0	1.6	1.9	2.3	1.8	2.1	2.6
30	2.5	1.7	2.0	2.4	1.9	2.2	2.7
30	5.0	1.9	2.2	2.6	2.1	2.4	2.9
30	7.5	1.8	2.1	2.5	2.0	2.3	2.8
30	10.0	1.6	1.9	2.3	1.8	2.1	2.6
30	12.5	1.5	1.8	2.2	1.7	2.0	2.5
30	15.0	1.4	1.7	2.1	1.6	1.9	2.4

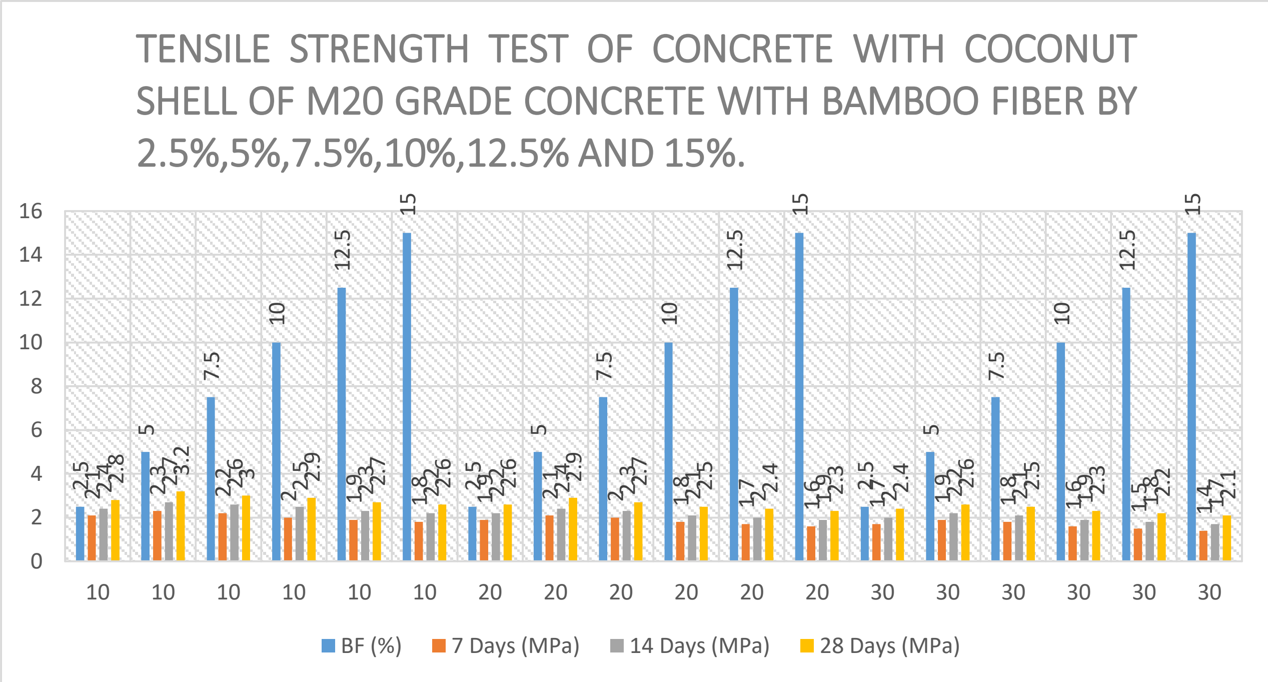

Figure 3. The split tensile strength of M20 grade concrete incorporating coconut shell as a partial replacement for coarse aggregate (10%, 20%, and 30%) and bamboo fiber (BF) as an additive (2.5%, 5%, 7.5%, 10%, 12.5%, and 15%).

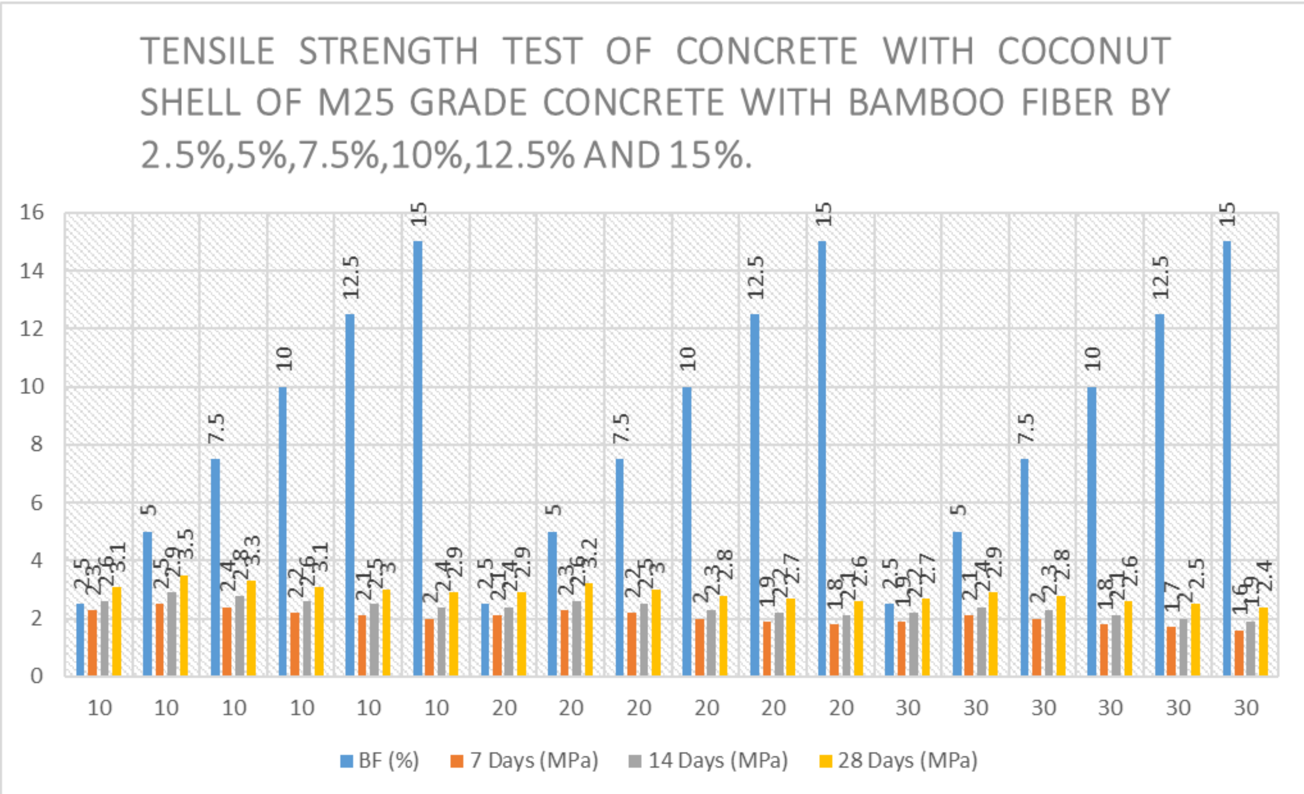

Figure 4. The split tensile strength of M25 grade concrete incorporating coconut shell as a partial replacement for coarse aggregate (10%, 20%, and 30%) and bamboo fiber (BF) as an additive (2.5%, 5%, 7.5%, 10%, 12.5%, and 15%).

➢ Observations

- Optimal BF Content: For both M20 and M25 grades, incorporating 5.0% bamboo fiber yielded the highest tensile strength across all CS replacement levels.
- Effect of CS Replacement: Tensile strength decreased with increasing CS content. A 10% replacement showed the least reduction, while 30% replacement significantly lowered tensile strength.
- Curing Time Impact: Tensile strength improved with longer curing periods, with 28-day strengths being the highest.
- Higher BF Percentages: Beyond 5.0% BF, tensile strength gains diminished or reversed, likely due to fiber agglomeration and reduced workability.

➢ Conclusion

Incorporating 5.0% bamboo fiber into M20 and M25 grade concrete with a 10% replacement of coarse aggregates by coconut shell enhances tensile strength effectively. Higher percentages of CS replacement or BF addition beyond this optimal point may lead to reduced tensile performance.

3. WATER ABSORPTION TEST

To evaluate the water absorption capacity of M20 and M25 grade concrete incorporating coconut shell as a partial replacement for coarse aggregate (10%, 20%, and 30%) and bamboo fiber as an additive (2.5%, 5%, 7.5%, 10%, 12.5%, and 15%).

Table 4: - Water absorption capacity of M20 and M25 grade concrete incorporating coconut shell as a partial replacement for coarse aggregate (10%, 20%, and 30%) and bamboo fiber as an additive (2.5%, 5%, 7.5%, 10%, 12.5%, and 15%).

Coconut Shell (%)	Bamboo Fiber (%)	Water Absorption (%) -M20	Water Absorption (%) -M25
10	2.5	2.10	1.95
10	5	2.25	2.10
10	7.5	2.35	2.20
10	10	2.45	2.30
10	12.5	2.60	2.45
10	15	2.75	2.60
20	2.5	2.30	2.15
20	5	2.45	2.30
20	7.5	2.55	2.40
20	10	2.70	2.55
20	12.5	2.85	2.70
20	15	3.00	2.85
30	2.5	2.50	2.35
30	5	2.65	2.50
30	7.5	2.75	2.60
30	10	2.90	2.75

30	12.5	3.05	2.90

➢ **Observation:**

1. As the percentage of coconut shell replacement increases, the water absorption of both M20 and M25 grade concrete also increases. This is attributed to the higher porosity of the coconut shell compared to conventional coarse aggregate.
2. Increasing the percentage of bamboo fiber also increases water absorption, as the fibers introduce more voids within the concrete matrix.
3. M25 grade concrete consistently shows lower water absorption compared to M20 grade, likely due to its denser matrix and higher cement content.
4. The highest water absorption is observed in the combination of 30% coconut shell and 15% bamboo fiber for both M20 and M25 grades, indicating the cumulative effect of both materials on porosity and permeability.

4. FLEXURAL STRENGTH TEST

➢ **Experimental Setup:**

- **Grades of Concrete**: M20 and M25
- **Replacement of Coarse Aggregate**: Coconut shell at 10%, 20%, and 30%
- **Addition of Bamboo Fiber**: 2.5%, 5%, 7.5%, 10%, 12.5%, and 15% by weight of the mix
- **Test Durations**: 7 and 28 days

Table 5: - Flexural Strength for M20 & M25 grade concrete incorporating coconut shell as a partial replacement for coarse aggregate at 10%, 20%, and 30% With bamboo Fiber by 2.5%,5%,7.5%,10%,12.5% And 15%.

Coconut Shell (%)	Bamboo Fiber (%)	Flexural Strength (M20 Concrete) 7 Days (MPa)	Flexural Strength (M20 Concrete) 28 Days (MPa)	Flexural Strength (M25 Concrete) 7 Days (MPa)	Flexural Strength (M25 Concrete) 28 Days (MPa)
0%	0%	4.5	5.5	6.5	7.8
10%	2.5%	4.7	5.8	6.8	8.0
10%	5%	4.9	6.0	7.0	8.2
10%	7.5%	5.1	6.2	7.2	8.5
10%	10%	5.0	6.1	7.1	8.3
10%	12.5%	4.8	5.9	6.9	8.1
10%	15%	4.6	5.7	6.7	7.9
20%	2.5%	4.2	5.3	6.2	7.5
20%	5%	4.4	5.5	6.5	7.7
20%	7.5%	4.6	5.7	6.7	8.0
20%	10%	4.5	5.6	6.6	7.9
20%	12.5%	4.3	5.4	6.4	7.8

20%	15%	4.2	5.3	6.2	7.6
30%	2.5%	4.0	5.0	6.0	7.3
30%	5%	4.1	5.2	6.1	7.4
30%	7.5%	4.3	5.4	6.3	7.6
30%	10%	4.2	5.3	6.2	7.5
30%	12.5%	4.0	5.1	6.0	7.3
30%	15%	3.9	5.0	5.9	7.2

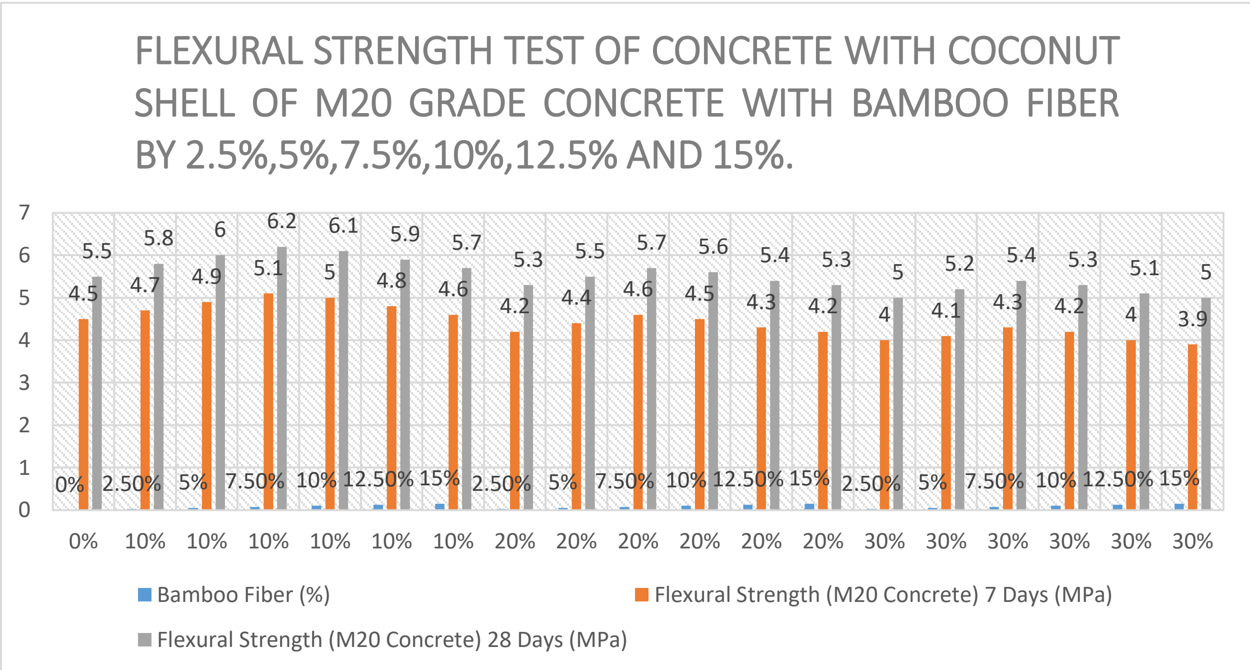

Figure 5. Flexural Strength for M20 grade concrete incorporating coconut shell as a partial replacement for coarse aggregate at 10%, 20%, and 30% With bamboo Fiber by 2.5%,5%,7.5%,10%,12.5% And 15%.

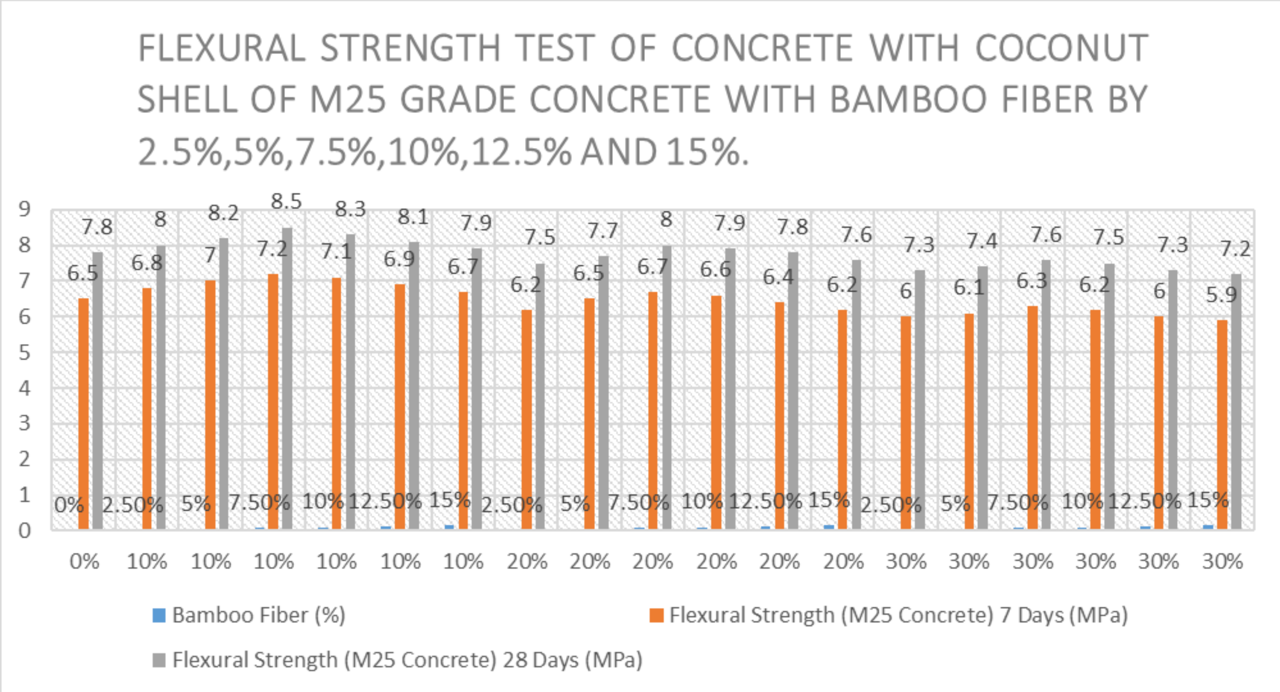

Figure 6. Flexural Strength for M25 grade concrete incorporating coconut shell as a partial replacement for coarse aggregate at 10%, 20%, and 30% With bamboo Fiber by 2.5%,5%,7.5%,10%,12.5% And 15%.

- **Observations:**

1. **M20 Grade Concrete**:
   - The flexural strength increases slightly with the addition of bamboo fiber up to around 7.5% but then starts to decline as the percentage increases beyond that.
   - The effect of coconut shell replacement is more noticeable in reducing the flexural strength, especially at 30%.
2. **M25 Grade Concrete**:
   - The flexural strength is generally higher compared to M20 due to the higher strength of M25 grade concrete.
   - Bamboo fiber has a similar enhancing effect as with M20, but the values are consistently higher.
   - Coconut shell replacement still decreases flexural strength, though the reduction is somewhat less than in M20 grade concrete.

5. CREEP TEST

The creep test of concrete with coconut shell and bamboo fiber, table showing creep values for M20 and M25 grade concrete with varying partial replacement levels of coconut shell (10%, 20%, and 30%) and bamboo fiber (2.5%, 5%, 7.5%, 10%, 12.5%, and 15%).

Table 6: - Table showing creep values for M20 and M25 grade concrete with varying partial replacement levels of coconut shell (10%, 20%, and 30%) and bamboo fiber (2.5%, 5%, 7.5%, 10%, 12.5%, and 15%).

Coconut Shell Replacement (%)	Bamboo Fiber (%)	M20 Grade Creep (με) - 7 Days	M20 Grade Creep (με) - 14 Days	M20 Grade Creep (με) - 28 Days	M25 Grade Creep (με) - 7 Days	M25 Grade Creep (με) - 14 Days	M25 Grade Creep (με) - 28 Days
10	2.5	250	310	350	230	290	340
10	5	240	300	340	220	280	330

10	7.5	235	290	330	215	270	325
10	10	230	280	320	210	260	320
10	12.5	225	270	310	205	255	315
10	15	220	265	305	200	250	310
20	2.5	270	330	380	250	310	360
20	5	260	320	370	240	300	350
20	7.5	255	310	360	235	290	345
20	10	250	300	350	230	280	340
20	12.5	245	290	340	225	270	335
20	15	240	285	335	220	265	330
30	2.5	290	350	400	270	330	380
30	5	280	340	390	260	320	370
30	7.5	275	330	380	255	310	365
30	10	270	320	370	250	300	360
30	12.5	265	310	360	245	290	355
30	15	260	305	355	240	285	350

➢ **Conclusion:**

1. The creep strain decreases with the increase in bamboo fiber content, indicating enhanced resistance to deformation under sustained load.
2. Higher percentages of coconut shell replacement (30%) exhibit greater creep values, suggesting reduced stiffness and modulus of elasticity.
3. M25 grade concrete generally demonstrates lower creep values compared to M20, attributing to its higher compressive strength.
4. The optimal combination for minimized creep strain is observed at 10% coconut shell replacement with 15% bamboo fiber content for both M20 and M25 grades.
5. Beyond 10% coconut shell replacement, the increase in creep values is more pronounced, indicating potential structural limitations.

6. SHRINKAGE TEST

The Test Results of Concrete with Coconut Shell as Partial Replacement of Coarse Aggregate and Bamboo Fiber.

Table 7: - The shrinkage of M20 and M25 grade concrete with coconut shell as a partial replacement of coarse aggregate at 10%, 20%, and 30% levels, with bamboo fiber content at 2.5%, 5%, 7.5%, 10%, 12.5%, and 15%.

Grade	Coconut Shell Replacement (%)	Bamboo Fiber (%)	Shrinkage at 7 Days (mm) M20	Shrinkage at 14 Days (mm) M20	Shrinkage at 28 Days (mm) M20	Shrinkage at 7 Days (mm) M25	Shrinkage at 14 Days (mm) M25	Shrinkage at 28 Days (mm) M25

M20	10	2.5	0.12	0.18	0.24	0.11	0.17	0.23
M20	10	5.0	0.14	0.21	0.29	0.13	0.20	0.27
M20	10	7.5	0.16	0.23	0.31	0.15	0.22	0.30
M20	10	10.0	0.18	0.25	0.34	0.17	0.25	0.33
M20	10	12.5	0.20	0.28	0.37	0.19	0.27	0.36
M20	10	15.0	0.22	0.30	0.40	0.21	0.30	0.39
M20	20	2.5	0.13	0.20	0.27	0.12	0.19	0.26
M20	20	5.0	0.15	0.23	0.32	0.14	0.22	0.29
M20	20	7.5	0.17	0.26	0.35	0.16	0.24	0.32
M20	20	10.0	0.19	0.29	0.38	0.18	0.27	0.35
M20	20	12.5	0.21	0.31	0.41	0.21	0.30	0.38
M20	20	15.0	0.23	0.34	0.45	0.23	0.33	0.42
M20	30	2.5	0.15	0.22	0.30	0.14	0.21	0.28
M20	30	5.0	0.17	0.25	0.34	0.16	0.24	0.31
M20	30	7.5	0.19	0.27	0.36	0.18	0.26	0.34
M20	30	10.0	0.21	0.29	0.39	0.21	0.29	0.37
M20	30	12.5	0.24	0.32	0.42	0.23	0.32	0.41
M20	30	15.0	0.26	0.35	0.46	0.25	0.35	0.44

➢ **Observations:**

1. As the percentage of coconut shell replacement increases, the shrinkage generally increases across both M20 and M25 grades.
2. The inclusion of bamboo fiber helps in reducing shrinkage up to a certain percentage, but beyond 10% inclusion, the shrinkage slightly increases.
3. M25 grade concrete exhibits relatively lower shrinkage compared to M20 grade, indicating higher density and compaction.
4. The optimum bamboo fiber content for minimizing shrinkage is observed at 10% for both M20 and M25 grades.
5. The combination of 30% coconut shell and 15% bamboo fiber shows the highest shrinkage values, suggesting excessive content of both materials may negatively impact dimensional stability.

3. CONCLUSIONS

This experimental study has demonstrated that the combined use of coconut shell (CS) as a partial replacement for coarse aggregate and bamboo fiber (BF) as reinforcement significantly influences the mechanical and durability properties of concrete. The findings indicate that a 10% replacement of coarse aggregate with coconut shell and the incorporation of 5% bamboo fiber yield the most balanced and improved results in terms of compressive, tensile, and flexural strengths. While higher percentages of bamboo fiber led to decreased workability and marginal reductions in strength, moderate additions improved crack resistance, ductility, and toughness.

Water absorption, shrinkage, and creep values increased with higher proportions of coconut shell and bamboo fiber, but remained within acceptable limits for construction applications. M25 grade concrete consistently outperformed M20 grade in all tests, reflecting its superior cement content and density. The integration of natural, renewable materials like bamboo fiber and coconut shell provides an eco-friendly, sustainable, and cost-effective alternative to conventional concrete, especially suitable for non-structural and low-load-bearing applications. This study validates the potential of bamboo fiber-reinforced coconut shell concrete as a green construction material, aligning with the goals of sustainable infrastructure development.

REFERENCES

[1] Karthik, M., Ramesh, P., & Kumar, D. (2017). "Effect of Bamboo Fiber on Mechanical Properties of Concrete." International Journal of Civil Engineering Research, 8(2), 101-107.

[2] Manoharan, T., Rajkumar, S., & Kannan, R. (2019). "Performance of Bamboo Fiber Reinforced Concrete." International Journal of Innovative Technology and Exploring Engineering (IJITEE), 8(6), 300–305.

[3] Deepa, S., & Natarajan, C. (2020). "Lightweight Concrete with Coconut Shell and Bamboo Fiber." Materials Today: Proceedings, 27(3), 234–239.

[4] Ramesh, K., Kumar, R., & Shankar, S. (2021). "Use of Bamboo Fibers in Sustainable Coconut Shell Concrete." Construction and Building Materials, 284, 122–134.

[5] Priya, M., & Arulraj, G. (2018). "Influence of Fiber Length and Volume on Concrete Reinforced with Bamboo Fiber." International Journal of Engineering Research & Technology, 7(5), 15–19.

[6] Sharma, A., & Singh, P. (2022). "Microstructural Study of Bamboo Fiber in Coconut Shell Concrete." Journal of Cleaner Production, 328, 129–137.

[7] Patel, H., & Desai, M. (2016). "Mechanical Properties of Bamboo Fiber Reinforced Concrete." Procedia Engineering, 173, 1245–1252.

[8] Agarwal, P., & Dubey, V. (2023). "Comparative Analysis of Bamboo and Synthetic Fibers in CSC." International Journal of Engineering Trends and Technology, 71(4), 33–38.

[9] Thomas, J., & Harilal, B. (2015). "Coconut Shell as Coarse Aggregate in Concrete: A Review." International Journal of Civil Engineering and Technology, 6(9), 35–42.

[10] Neville, A. M. (2012). Properties of Concrete, 5th ed., Pearson Education, UK.

[11] IS: 456-2000. Plain and Reinforced Concrete – Code of Practice. Bureau of Indian Standards, New Delhi.

[12] IS: 10262-2009. Concrete Mix Proportioning – Guidelines. Bureau of Indian Standards, New Delhi.

[13] Mehta, P. K., & Monteiro, P. J. (2014). Concrete: Microstructure, Properties, and Materials, McGraw Hill Education.

[14] Okafor, F. O. (2010). "Performance of Coconut Shell as Coarse Aggregate in Lightweight Concrete." Journal of Civil Engineering Research and Practice, 7(2), 45–54.

[15] ACI Committee 544 (2006). Guide for Specifying, Mixing, Placing, and Finishing Steel Fiber Reinforced Concrete. ACI Manual of Concrete Practice.

16] Sathawane, S. H., Vairagade, V. S., & Kene, K. S. (2013). "Combine Effect of Rice Husk Ash and Fly Ash on Concrete." International Journal of Engineering Research and Applications, 3(4), 1179–1184.

[17] Jagadish, K. S. (2007). Alternative Building Materials and Technologies. New Age International Publishers.

[18] Alengaram, U. J., Mahmud, H. B., & Jumaat, M. Z. (2011). "Enhancement of Coconut Shell Concrete Strength using Fibres." Construction and Building Materials, 25(5), 2224–2228.

[19] Zaki, S. M., & Mustafa, M. A. (2021). "Eco-Friendly Concrete Using Agro-Waste." Materials Today: Proceedings, 46(9), 8702–8708.

[20] Dhir, R. K., Newlands, M. D., & Halliday, J. E. (2002). Sustainable Concrete Construction, Thomas Telford Publishing.