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STUDY ON IMPROVEMENT OF STRENGTH OF CONCRETE BY USING NATURAL COCONUT FIBER

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Abstract: Natural fibers such as coir, jute, and bamboo are renewable resources that offer high tensile strength and low environmental impact compared to traditional synthetic fibers. The study aims to determine the effects of different proportions of natural coconut fiber on the compressive strength of concrete. This research contributes to developing eco-friendly concrete materials that can reduce the construction industry's carbon footprint while maintaining structural integrity. Moreover, using natural fibers offers ecological advantages by reducing the reliance on non-renewable resources and lowering the carbon footprint of concrete production. The results indicate that adding natural fibers improves the toughness and crack resistance of concrete, making it a viable alternative for sustainable construction practices. The compressive strength test of concrete cubes incorporating artificial fiber named recron in the same proportion as natural fiber was also performed to compare the results.

Keywords: Natural coconut fibers, Compressive strength, Crack resistance, Sustainable Construction practices, Artificial reconfiber.

I. INTRODUCTION

1. General:

Concrete is one of the most widely used construction materials globally due to its strength, durability, and versatility. However, traditional concrete has certain limitations, such as its brittleness, low tensile strength, and susceptibility to cracking under stress. These weaknesses often result in reduced durability and performance over time, leading to higher maintenance costs and potential structural failure. Additionally, the environmental impact of conventional concrete production, which is responsible for significant carbon emissions due to the use of cement and other non-renewable resources, has raised concerns in the construction industry.

As the demand for more sustainable and durable construction materials grows, researchers have increasingly turned to alternative methods of improving concrete properties. One such method is the incorporation of natural fibers, which offer an eco-friendly solution while improving the mechanical performance of concrete. Among the various natural fibers, coconut fiber, or coir, has gained attention due to its availability, cost-effectiveness, and sustainability. Coir is a biodegradable, renewable resource obtained from the husk of coconuts, making it an attractive option for improving the mechanical properties of concrete.

2. Description of Additive Materials:

2.1. Natural Coconut fiber:

In this project, coconut fiber is used as a natural fiber to enhance the strength and durability of concrete. These fibers are used in a length of 30-50 mm and a thickness of 0.5-1 mm, in a small proportion of around 0.5% and 1% of the cement volume. Coconut fibers, also known as coir fibers, are natural fibers extracted from the husk of coconuts and have gained popularity as an eco-friendly reinforcement material in the concrete mix design. These fibers are biodegradable, renewable, and abundantly available, making them a sustainable choice for construction applications. When added to concrete, coconut fibers improve its tensile strength, toughness, and resistance to cracking. The fibers help to bridge small cracks and distribute stress more evenly throughout the material, reducing the risk of sudden failure. Also, the addition of such fibers is effective against bending in horizontal members like beams. The concrete with added fibers may be

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considered durable because the fibers are encapsulated within the concrete mix after casting. This encapsulation isolates the fibers from direct contact with water, air, and external environmental factors that typically cause decomposition or degradation.

2.2. Artificial Recron fiber:

Recron fibers are synthetic fibers used in fiber-reinforced concrete to enhance the properties of concrete in many ways. Reliance Industry Limited (RIL) has launched Recron Fibers to improve the quality of plaster and concrete. Recron is a triangular polyester fiber in cross-section with cut lengths of 6mm & 12mm, being widely used in the Indian construction industry market. Recron Fiber Reinforced Concrete gives micro reinforcement, which reduces surface cracks, permeability, and degradation of concrete, ultimately reducing abrasion damage to the surface. FRC improves the toughness of concrete, average Residual Strength, and flexural strength, enhancing durability. It improves impact strength considerably. Artificial fiber-reinforced concrete cubes were cast to draw a comparative study on the compressive strength of cubes with and without natural fiber-reinforced concrete.

Fig 1: Natural Coconut Fiber

Fig 2: Artificial Recron Fiber

II. LITERATURE REVIEW

1. (**Thou, 2005**) mentioned in his research study the advantages of fiber-reinforced concrete over other construction materials, which are their high tensile strength-to-weight ratio, ability to be molded into various shapes, and potential resistance to environmental conditions, resulting in potentially low maintenance cost. Their application in construction includes both upgrading existing structures and building new ones, which can apply to various types of structures, for example, offshore platforms, buildings, and bridges.

2. (**Bhatia, 2001**) studied the usefulness of fiber-reinforced concrete in various civil engineering applications, which revealed that the fibrous material increases structural integrity. These studies made us adopt natural fibers, which are abundantly available and cheap.

3. (**Habibunnisa Syed et al.,2020**) conducted a study on coconut fiber-reinforced concrete, and the study highlights the optimal fiber content and water-cement ratio for concrete, emphasizing that 0.6%-1.2% coconut fiber with a water-cement ratio of 0.40 yields the best compression strength due to improved bonding between fibers and the mix at initial stages.

4. (**M. Prabu et al., 2019**) conducted a study on Experimental Investigation on Concrete Using Recron Fiber as Reinforcement, and from the experimental results, it is clear that the strength of concrete increases when Recron fiber is added to it. It is found that the strength of concrete increases gradually from 0.25% and then decreases in 1% of recron fiber in concrete. M20, M25, M30, and M35 grades of concrete showed better results for 0.75% of recron in concrete.

III. METHODOLOGIES

❖ **Testing of Aggregates:**

1. The grade of the sand was determined using sieve analysis as per IS 2386(Part 1)-1963.
2. The grade of the coarse aggregate was determined using sieve analysis as per IS 2386(Part 1)-1963.

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3. The specific gravity of the aggregate, i.e., fine aggregate and coarse aggregate (of sizes 10mm and 20mm), were determined as per IS 2386(Part 3)-1963.

4. The water absorption of the aggregate samples of fine aggregate and coarse aggregate (of sizes 10mm and 20mm) were determined as per IS 2386(Part 3)-1963.

❖ **Concrete Mix Proportioning and determining compressive strength:**

(i) Concrete mix without fibers (Control mix):

Concrete without any fibers is designed as a control mix to serve as the baseline for evaluating the impact of fibers on compressive strength. The design is based on the guidelines of IS 10262:2019. The mix proportions are designed for three different water-cement (w/c) ratios, as follows:

- Mix 1: 1:1.50:2.57 (Cement: Sand: Aggregate) with w/c = 0.44
- Mix 2: 1:1.60:2.69 (Cement: Sand: Aggregate) with w/c = 0.46
- Mix 3: 1:1.70:2.82 (Cement: Sand: Aggregate) with w/c = 0.48

Based on the volume of concrete required, the quantities of cement, sand, aggregate, and water are calculated for different mixes as per the water-cement ratio, following IS 10262 guidelines. Mixing is carried out by combining these materials in specified proportions. Six cubes (150 mm x 150 mm x 150 mm) were cast for each mix to evaluate compressive strength at different curing ages: 3 cubes each for 7-day and 28-day strength. Specimens are cured in water at 27 ± 2°C following IS 516:1959. Compressive strength testing is conducted as per IS 516:2018 standards at 7 and 28 days.

(ii) Concrete mix with natural coconut fibers:

Natural coconut fibers are incorporated into the mix to enhance the mechanical properties of concrete. The inclusion of coconut fibers is based on their weight relative to cement (0.5% and 1%), following research practices and experimental validation. The same mix proportions were designed for three of the same water-cement ratios.

Concrete quantities for cement, sand, aggregate, and water are calculated based on the required volume and water-cement ratio, following IS 10262 guidelines. 0.5% and 1% coconut fiber by weight of cement were incorporated into the dry mix, ensuring uniform distribution. The following procedure followed is the same as that for the control mix.

(iii) Concrete mix with artificial Recron fibers:

Synthetic fibers, i.e., Recron, are added to draw a comparison of the strength of fiber-reinforced concrete for both natural and artificial fiber. The fiber content is maintained at 0.5% and 1% by weight of cement, as per experimental research.

Concrete quantities for cement, sand, aggregate, and water are calculated based on the required volume and water-cement ratio, following IS 10262 guidelines. 0.5% and 1% recron fiber by weight of cement was incorporated into the dry mix ensuring uniform distribution. The following procedure followed is the same as that for the control mix.

The compressive strength results are compared to the control mix to evaluate the effect of both natural and synthetic fibers.

IV. RESULTS AND DISCUSSIONS

1. Gradation of fine aggregate:

The fine aggregate conforms to Grading Zone III as per IS 383:2016, with cumulative percentage passing values within specified limits. The fineness modulus of the sample was calculated to be 3.196.

2. Gradation of Coarse Aggregate:

From the experimental data, it is relevant that the coarse aggregate conforms to IS 383:2016, where the cumulative percentage passing values fall within the specified limits for a graded aggregate of 20mm nominal size. The graded aggregate was prepared using a mix of 60% 20 mm single-sized aggregate and 40% 10 mm single-sized aggregate, which contributes to the observed particle size distribution.

3. Specific gravity of the aggregate:

The specific gravity of the sample of 20mm Coarse aggregate, 10mm Coarse aggregate, and Fine aggregate are 2.82, 2.79, and 2.85, respectively. As per IS 2386 (Part III): 1963, the specific gravity of aggregates typically ranges between

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2.5 to 3.0. The obtained specific gravity values for all the samples fall within this range, indicating that the aggregates are of standard quality and suitable for concrete production.

4. Water Absorption of aggregates:

From the experimental data, it was determined that Water absorption of 20mm Coarse aggregate, 10mm Coarse aggregate, and Fine aggregate is 0.7%, 0.8%, and 1.5%, respectively. According to IS 2386 (Part 3): 1963 ("Methods of Test for Aggregates for Concrete"), water absorption should generally not exceed 3% for coarse aggregates and 2% for fine aggregates. The measured values are well within the permissible limits, indicating that the aggregates are suitable for concrete production.

5. Compressive strength of the concrete:

After curation of the test specimens, 7 days and 28 days compressive strength of the blocks has been calculated as per IS 456:2000. The strengths of the respective blocks are listed in the tables below:

(i) WATER CEMENT RATIO = 0.48:

- 7 days Compressive strength:

Table 4.51: Observations of 7 days compressive strength of concrete cubes with w/c =0.48

Sl. no.	**Cube Description**	**Compressive strength in N/mm^2**			**Average Compressive Strength in MPa**	**Maximum Compressive strength in MPa**
		SAMPLE I	**SAMPLE II**	**SAMPLE III**		
1.	NORMAL CUBES	17.33	19.56	15.11	17.33	19.56
2.	CUBES WITH NATURAL FIBER (0.5%)	24.44	24.44	24.44	24.44	24.44
	CUBES WITH NATURAL FIBER (1%)	19.11	18.67	20	19.26	20
3.	CUBES WITH ARTIFICIAL FIBER (0.5%)	20	21.33	20.89	20.74	21.33
	CUBES WITH ARTIFICIAL FIBER (1%)	14.22	17.33	17.78	16.44	17.78

- 28 days Compressive strength:

Table 4.52: Observation of 28 days compressive strength of concrete with w/c=0.48

Sl. No.	**Cube Description**	**Compressive strength in N/mm2**			**Average Compressive Strength in MPa**	**Maximum Compressive strength in MPa**
		SAMPLE I	**SAMPLE II**	**SAMPLE III**		
1.	NORMAL CUBES	24.44	35.11	32.89	30.81	35.11
2.	CUBES WITH NATURAL FIBER (0.5%)	34.22	33.33	33.33	33.63	34.22
	CUBES WITH NATURAL FIBER (1%)	26.67	26.22	28	26.96	28
3.	CUBES WITH ARTIFICIAL FIBER (0.5%)	33.33	33.11	32	32.15	33.33
	CUBES WITH ARTIFICIAL FIBER (1%)	23.11	23.11	23.56	23.26	23.56

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(ii)WATER CEMENT RATIO=0.46

- 7 days compressive strength:

Table 4.53: Observations of 7 days compressive strength of concrete with w/c=0.46

Sl. No.	Cube Description	Compressive strength in N/mm2			Average Compressive Strength in MPa	Maximum Compressive Strength in MPa
		SAMPLE I	SAMPLE II	SAMPLE III		
1.	NORMAL CUBES	24.44	23.56	28.44	25.48	28.44
2.	CUBES WITH NATURAL FIBER (0.5%)	24	24.89	20	22.96	24.89
	CUBES WITH NATURAL FIBER (1%)	18.67	17.78	18.67	18.37	18.67
3.	CUBES WITH ARTIFICIAL FIBER (0.5%)	18.22	21.33	20.89	20.15	21.33
	CUBES WITH ARTIFICIAL FIBER (1%)	13.33	13.78	15.56	14.22	15.56

- 28 days compressive strength:

Table 4.54: Observations of 28 days compressive strength of concrete cubes with w/c=0.46

Sl. No.	Cube Description	Compressive strength in N/mm2			Average Compressive Strength in MPa	Maximum Compressive Strength in MPa
		SAMPLE I	SAMPLE II	SAMPLE III		
1.	NORMAL CUBES	32.44	39.11	36	35.85	39.11
2.	CUBES WITH NATURAL FIBER (0.5%)	28.89	24	29.78	27.56	29.78
	CUBES WITH NATURAL FIBER (1%)	26.67	24.44	24	25.04	26.67
3.	CUBES WITH ARTIFICIAL FIBER (0.5%)	26.22	18.22	24.44	22.96	26.22
	CUBES WITH ARTIFICIAL FIBER (1%)	22.22	19.56	20.44	20.74	22.22

(iii) WATER CEMENT RATIO= 0.44:

- 7 days compressive strength:

Table 4.55: Observations of 7 days compressive strength of concrete cubes with w/c=0.44

Sl. No.	Cube Description	Compressive strength in N/mm2			Average Compressive Strength in MPa	Maximum Compressive Strength in MPa
		SAMPLE I	SAMPLE II	SAMPLE III		
1.	NORMAL CUBES	22.67	28.44	27.11	26.07	28.44
2.	CUBES WITH NATURAL FIBER (0.5%)	26.67	28.44	26.22	27.11	28.44
	CUBES WITH NATURAL FIBER (1%)	20	21.78	22.67	21.48	22.67
3.	CUBES WITH ARTIFICIAL FIBER (0.5%)	24	26.22	25.33	25.18	26.22
	CUBES WITH ARTIFICIAL FIBER (1%)	18.22	18.67	19.56	18.82	19.52

- 28 days compressive strength:

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Table 4.56: Observations of 28 days compressive strength of concrete cubes with w/c=0.44

Sl. No.	Cube Description	Compressive strength in N/mm2			Average Compressive Strength in MPa	Maximum Compressive Strength in MPa
		SAMPLE I	SAMPLE II	SAMPLE III		
1.	NORMAL CUBES	39.56	40.89	40.44	40.30	40.89
2.	CUBES WITH NATURAL FIBER (0.5%)	35.56	35.11	33.78	34.82	35.56
	CUBES WITH NATURAL FIBER (1%)	24.22	26.22	26.67	25.78	26.67
3.	CUBES WITH ARTIFICIAL FIBER (0.5%)	27.56	31.11	28.44	29.04	31.11
	CUBES WITH ARTIFICIAL FIBER (1%)	23.56	22.22	21.78	22.52	23.56

DISCUSSIONS FOR THE RESULTS OBTAINED USING GRAPHS:

The following graphs illustrate the relationships between 7th and 28th day compressive strength, water-cement ratio, and the influence of additives like natural and artificial fibers (0.5% and 1%) and their optimal percentages:

A. 7 days maximum compressive strength vs cube types:

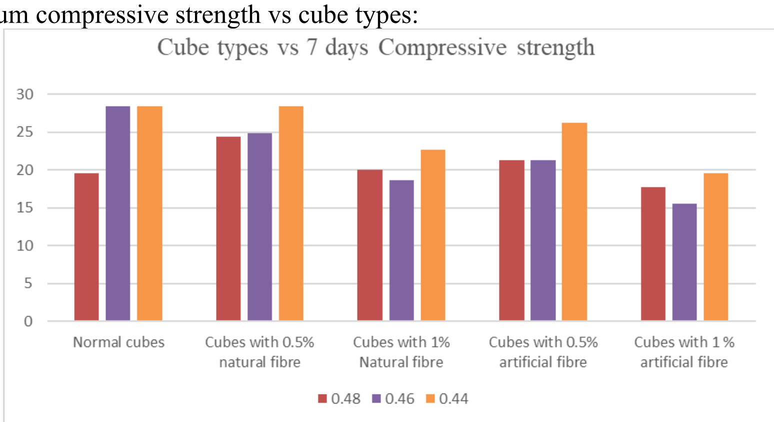

Fig 4.1: Graph showing cube types vs compressive strength for different water-cement ratios

The chart shows the 7th -day compressive strength of concrete cubes with water-cement ratios of 0.48, 0.46, and 0.44 and fiber reinforcements. It can be interpreted that normal cubes give the highest strength, and natural fibers do better than artificial fibers. Moreover, decreasing the water-cement give higher strength for all types of cubes. Also, 0.5% fiber reinforced cube has higher strength performance compared to 1% fiber-reinforced cubes.

B. 28 days maximum compressive strength vs cube types:

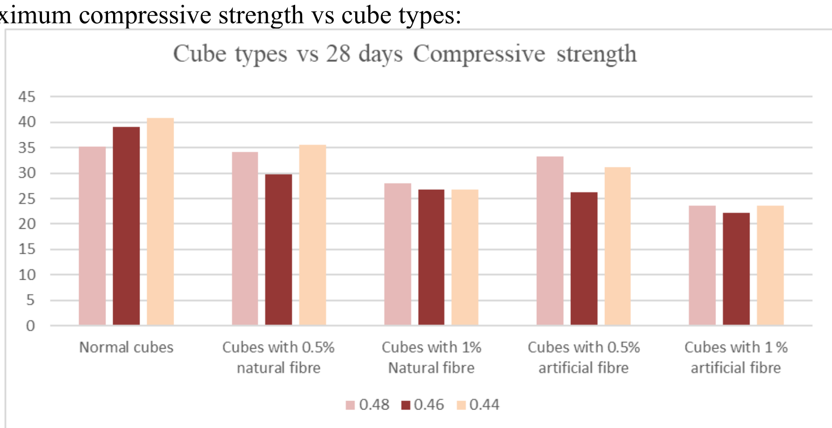

Fig 4.2: Graph showing cube types vs. 28 days compressive strength for different w/c ratios

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From the graph, it can be interpreted that normal cubes yield the highest 28-day compressive strength for all water-cement ratios. Strength increases with a decreased water-cement ratio. Though normal cubes have the highest compressive strength, natural fibers perform better than artificial fibers. Cubes with 0.5% fiber reinforcement perform better than 1% fiber reinforcement. The compressive strength of the 1% artificial fiber content cubes is the least of all.

C. Effect of fiber percentage on 28 days average compressive strength of the cubes for different water-cement ratio:

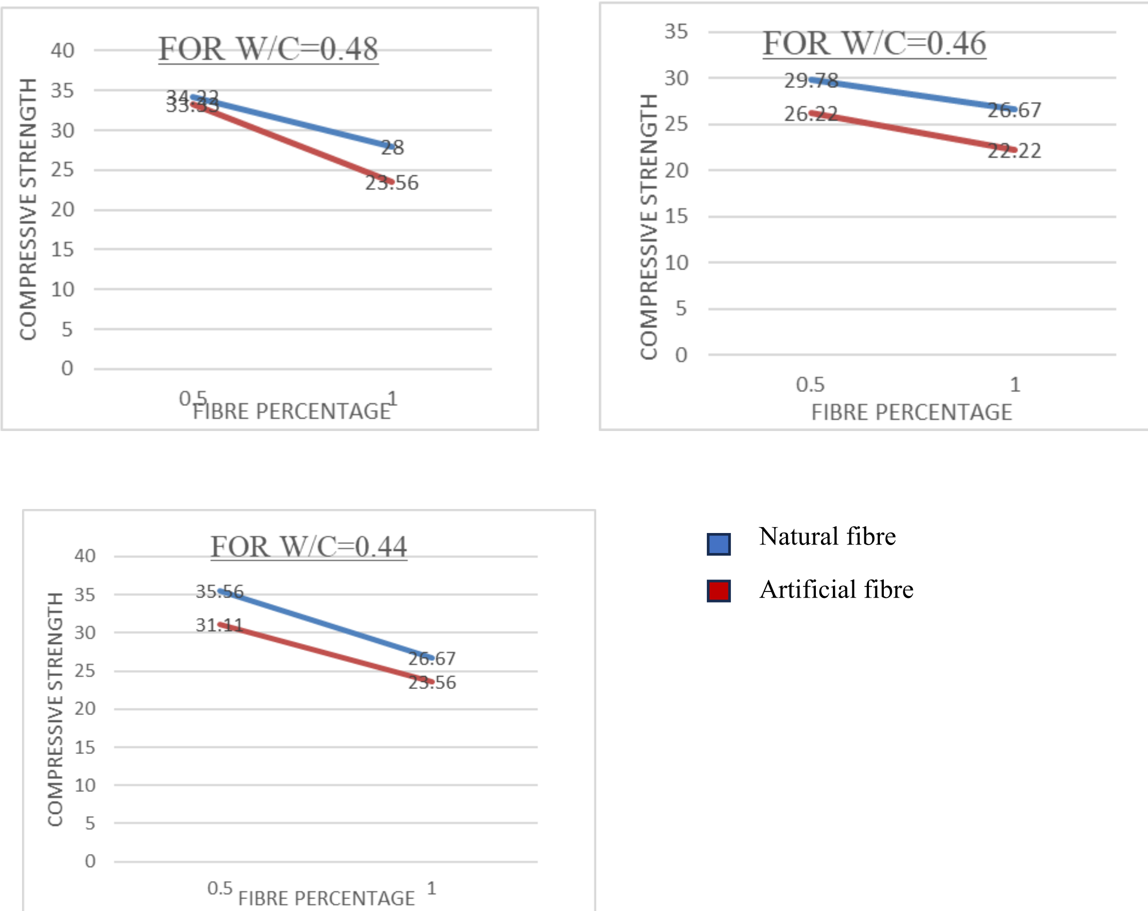

Fig 4.3: Graphs showing the effect of fiber content on 28 days of compressive strength

Both natural and artificial fibers experience a decrease in compressive strength as fiber content increases from 0.5% to 1% at all water-cement ratios. However, natural fibers consistently result in all water-cement ratios, 0.5% fiber content is optimal, as it yields higher compressive strength compared to 1%, with natural fibers performing better than artificial fibers.

V. ANALYSIS

From the results obtained, the different strength behavior of the cubes on the 7th day and 28th day and weight analysis for different water-cement ratios and fiber-reinforced percentages have been analyzed in detail in the following:

1. At water-cement ratio = 0.48

A. 7th day compressive strength analysis:

- A significant increase in strength of 41.03% is observed when 0.5% natural fibers are added compared to normal cubes.
- When increasing from 0.5% to 1% natural fibers, the strength decreases drastically by 21.19%, suggesting diminishing returns or adverse effects at higher fiber content.
- 0.5% artificial fibers result in a moderate 19.68% strength increase from normal cubes, showing artificial fibers' positive impact. But on increasing the fiber content from 0.5% to 1%, the strength decreases.

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- Comparing 0.5% artificial fibers to 0.5% natural fibers results in a notable 32.73% reduction in strength from 24.44KN to 16.44KN for 0.5% natural fiber reinforced concrete to 0.5% artificial fiber reinforced concrete, favoring natural fibers over artificial ones.

B. 28th day compressive strength analysis:

- Adding 0.5% natural fibers increases strength by 9.15% from normal cubes, showing moderate long-term benefits.
- Increasing to 1% fiber content decreases strength by 19.83%, reinforcing that higher natural fiber content is detrimental.
- Artificial fibers at 0.5% provide a 4.35% strength increase from normal cubes, which is lower than the strength yield by natural fiber at 0.5%.
- Switching to artificial fibers leads to a 30.84% reduction, suggesting natural fibers outperform artificial ones in the long term.

2. At water-cement ratio = 0.46:

A. 7th day compressive strength analysis:

- The addition of 0.5% natural fibers causes a 9.89% decrease in strength, indicating that natural fibers negatively affect performance for this mix.
- Increasing fiber content to 1% further reduces strength by 19.99%, confirming a compounding negative impact. This may be due to casting error or the effect of fiber.
- Artificial fibers at 0.5% also lead to a 20.92% strength decrease compared to normal cubes.
- Moving from 0.5% natural to artificial fibers results in a 38.07% reduction, showing artificial fibers perform worse at this ratio.

B. 28th day Compressive strength analysis:

- Adding 0.5% natural fibers decreases strength by 23.12%, showing significant negative effects.
- Increasing to 1% fibers reduces strength by 9.14%, confirming adverse effects at higher content.
- Artificial fibers result in a 35.96% reduction, indicating poor performance.
- Switching to artificial fibers leads to a smaller 24.75% reduction, though both fiber types perform poorly.

3. At water-cement ratio = 0.44

A. 7th day compressive strength analysis:

- A small 3.99% strength gain is seen with 0.5% natural fibers, indicating minor improvements.
- Increasing fiber content to 1% causes a 20.77% strength loss, continuing the diminishing returns trend.
- Artificial fibers result in a 3.41% decrease, indicating neutral to slightly negative effects.
- The change from 0.5% natural to artificial fibers results in a 30.58% reduction, making natural fibers more effective.

B. 28th day compressive strength analysis:

- A 13.60% decrease in strength is observed with 0.5% natural fibers, highlighting a lack of benefit at this ratio.
- Increasing to 1% fibers results in a further 25.96% reduction, consistent with earlier findings.
- Artificial fibers decrease strength by 27.94%, which is worse than natural fibers.
- Switching from natural to artificial fibers results in a 35.32% reduction, indicating artificial fibers are less effective.

VI. CONCLUSION

Based on the analysis, the optimal fiber content is 0.5% natural fibers for a water-to-cement (w/c) ratio of 0.48. At this ratio, the strength increases significantly for both short-term (7th day: 41.03%) and long-term (28th day: 9.15%) compared to normal cubes. However, increasing the natural fiber content to 1% leads to a considerable reduction in strength across all w/c ratios, indicating diminishing returns or possible adverse effects of higher fiber content.

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Artificial fibers generally perform worse than natural fibers, showing strength reductions at all tested w/c ratios. For 0.46 and 0.44 w/c ratios, adding fibers (both natural and artificial) mostly results in reduced strength, making these mixes less favorable for fiber addition. Thus, 0.5% natural fibers at 0.48 w/c ratio are the most effective combination for improving concrete strength, offering substantial short-term gains while maintaining moderate long-term performance. Lower w/c ratios and higher fiber content should be avoided due to their negative impact on strength.

Fiber-reinforced concrete can be expected to enhance strength, durability, and ductility by reducing cracks and improving resistance to bending and environmental stresses. It can be considered a reliable and versatile material for structures requiring enhanced performance and long-term durability.

VII. SCOPE FOR FUTURE STUDY

- The effect of coconut fibers on high-strength concrete should be studied, and thus, the use of coconut fiber-reinforced concrete can be extended to industrial and commercial buildings.
- Since the durability study is not done, the applicability of Coconut Fiber fiber-reinforced concrete in reinforced constructions may be tested.
- The natural coconut fiber may also be used in concrete to enhance its strength against bending.

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