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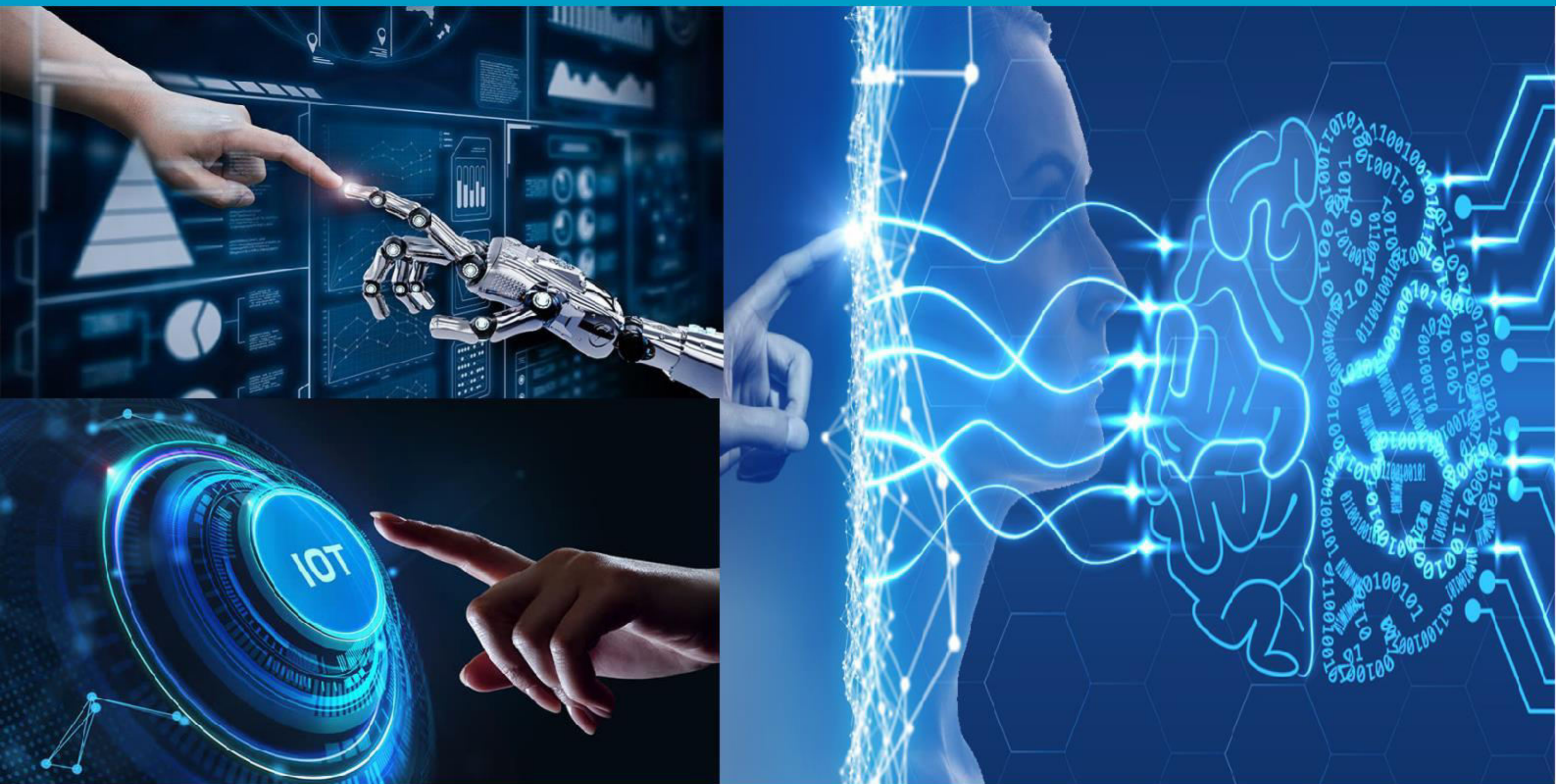

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Increase in Tensile Strength of Plain Concrete using Oil Palm Fibre

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ABSTRACT: This study assesses how oil palm fibre affects concrete's workability and mechanical qualities as an additive. The fibre levels of the concrete mixes were varied and examined at 7, 14, 21, and 28 days after curing. The fibre contents were 0.0%, 0.5%, 1.0%, and 1.5%. In order to determine whether oil palm fibre is a suitable sustainable material for concrete production, important tests were carried out, including compressive strength, tensile strength, and slump tests. According to the results of the slump test, workability decreased as the fibre content increased. The 0.5% and 1.5% mixes recorded slump values of 120 mm and 60 mm, respectively, while the control mix (0.0%) had the greatest slump value of 150 mm, suggesting decreased workability with increasing fibre concentration. According to compressive strength testing, the 0.5% mix had a similar strength of 15.35 N/mm² at 7 days, whereas the control mix had the maximum early strength at 16.25 N/mm². As a result of matrix disruption, higher fibre contents (1.0% and 1.5%) showed decreased strengths of 11.60 N/mm² and 13.05 N/mm², respectively. Strength and durability were optimally balanced at 28 days, with the 0.5% mix achieving 15.85 N/mm² and the control mix reaching 17.70 N/mm².The results of the tensile strength test indicated that the 0.5% mix performed better than the others, reaching 3.50 N/mm² at 28 days as opposed to 3.25 N/mm² for the control mix. The strength development was delayed in the 1.0% and 1.5% mixtures, which recorded 3.25 N/mm² and 3.15 N/mm², respectively, and higher fibre concentrations. The best additive, according to the results, is 0.5% oil palm fibre, which increases tensile strength while preserving workability and proper compressive strength. The utilisation of agricultural waste for environmental sustainability is advanced by this study, which highlights the potential of oil palm fibre as a sustainable material in the manufacturing of concrete.

KEYWORDS: workability, compressive strength, tensile strength, oil palm fibre, and sustainable building.

I. INTRODUCTION

One of the best ways to achieve sustainability is to use natural resources and waste materials appropriately for building and construction applications. The building industry is the one that uses natural resources the most. The main component of buildings is concrete, which is regarded as the second most used material after water. Massive quantities of material resources are needed to produce concrete [1][2][3]. Concrete has strong compressive strength but weak tensile strength and strain properties, and it cracks rapidly when exposed to bending or tensile strains.Concrete has this drawback, but methods to make reinforced concrete a composite construction composed of reinforcement have been devised to get around it. Construction and building projects are more expensive due to the high cost of steel reinforcement.

Because of this, several researchers created innovations to add fibres, admixtures, and other cementitious elements to the concrete in order to improve its tensile and strain characteristics [4][5][6] . This will minimise the amount of reinforcement needed, lowering the overall cost of construction [2][7]. Fibres may be used as primary or secondary reinforcement in cementitious composites [8][9]. Fibres are added as the main reinforcement to thin-sheet products when conventional steel reinforcements cannot be used. This type of thin-sheet product contains a lot of cement and no coarse elements in the matrix. The fibres prevent cracks from developing and spreading while also increasing toughness, impact resistance, and tensile strengths.

The use of fibres as secondary reinforcement improves the post-cracking load resistance due to overload or spalling and controls the formation of cracks and their spread induced by temperature changes or humidity[10][11]. A variety of fibre types, including natural and synthetic fibres added in different sizes, have been used to improve cementitious composites. The selection of fibres is influenced by the type of cementitious composite, availability, cost, and the need to improve the composite's properties.

Synthetic materials commonly used include steel, glass, carbon fibres, polypropylene, polyethylene, polyvinyl alcohol, and polyvinyl chloride [11]. Natural fibres come from natural resources like trees, plants, flora, and animals. Among their attributes are low elasticity and high tensile strength [7][12].

Furthermore, natural fibres have a few advantages over synthetic and substitute fibres. These include improved thermal and acoustic properties, decreased density and abrasiveness, enhanced resistance to alkalinity, low to zero cost, restricted accessibility, and more [13][14]. However, compared to synthetic fibres, natural fibres are less wettable and have a worse bond with the cement matrix due to their hydrophilia[7] [10].

Oil palm fibre (OPF) is a completely natural, non-toxic, and biodegradable material that can be used to improve the properties of concrete. Oil palm's vascular bundles are utilised to produce oil palm fibre (OPF) from empty fruit bunches (EFBs), which are thrown away after processing fresh fruit bunches (FFB). Therefore, there will be a large waste discharge if EFB is not managed properly. Around 57.6% of the world's total palm oil supply comes from oil palm, which is grown on more than three million hectares [15][16][17].

This indicates that Malaysia has a high density (1200 kg/mm3), high tensile strength (300-600 N/mm2), and a high lignin content (24.03%) of natural fibre[17][18]. Oil palm waste products, including as leaves, trunks, and bunches, should thus be fully utilised in the building and other construction industries.

The effectiveness of OPF has not been extensively studied because most research has concentrated on using oil palm trunk fibre[17][18][19] and oil palm shell [20][21][22] to improve concrete performance. Examining the suitability of OPF as a concrete addition was the aim of this investigation. The impact of OPF content on compressive strength and workability was also emphasised.

Many research on concrete mixtures, including OPF, have chosen the compressive test for concrete as the fundamental test since it is the main criterion for assessing the quality of natural-fiber reinforced concrete [19]. The workability and compressive strength of concrete mixtures are significantly impacted by the OPF content, according to earlier research.

II. LITERATURE REVIEW

Because of their mechanical qualities and environmental advantages, natural fibres are increasingly being used as reinforcement in concrete. There are still unresolved problems regarding how different natural fibre composites function, especially in varied environmental and load scenarios.

[23] examined six cylindrical specimens, each 520 mm long, in a four-point bending setup to examine the flexural performance of coconut fiber-reinforced concrete (FRC) confined with flax fiber-reinforced polymer (FRP) tubes. Two configurations were analysed: single tube specimens with an exterior flax fiber-reinforced polymer and double tube specimens with both an external and an internal polymer tube along the concrete cylinder. This underscores the need for more research on natural fibre composites, such as oil palm fibre, to improve the properties of concrete.The result shows that the inner flax fibre polymer tube's additional longitudinal reinforcement enhances the double flax fibre reinforced polymer's flexural behaviour in terms of flexural stiffness and ultimate load bearing capacity. The sudden loss of flexural strength is postponed by the inner flax fibre reinforced polymer tube, which stops slippage between the flax fibre polymer tubes and the coconut fibre reinforced composite core.

[24]looked into the use of coir fibres as reinforcement materials for cementitious composites by examining the behaviour of untreated and alkali-treated coir fibres in concrete using a scanning electron microscope (SEM) to look at the fibres' microstructures. The results showed that plain concrete (PC) cracked completely during testing, but coir fiber-reinforced concrete (CFRC) showed visible cracks held together by the coir fibres, proving the usefulness of coir fibres as secondary reinforcement to stop cracks from spreading and filling in concrete gaps.

Coir fibres used in this study that were alkali-treated with a 5% NaOH solution exhibited a rougher and cleaner surface than untreated coir fibres. Compared to regular concrete, the addition of coir fibre increases compressive strength. In comparison to CFRC that has not been treated, the alkali treatment can greatly increase compressive stress and strain. SEM investigations show that fibre breaking, fibre pull-out, and fibredebonding from the matrix are the failure modes of CFRC. In addition to the usual fibre breakage in the load direction, bending and splitting patterns of fibre breakage are also observed.

According to [25] who provided an overview of coir fiber and coir fiber-reinforced polymer composites, fiber treatment specifically alkalization with NaOH enhances matrix interfacial adhesion and improves composite properties. The study further revealed that the mechanical properties of composites depend on both the matrix and fiber content, while scanning electron microscopy (SEM) analysis showed that treated fibers reduce voids caused by fiber pull-out, whereas untreated fibers are more prone to water absorption.

[26]examined the physical and mechanical characteristics of cement boards made of coir fibres and contrasted them with traditional wood-cement boards used for ceiling tiles. Coir fibre cement board was made by combining the fibres with cement paste, putting the material in a 150 x 300 mm mould, pressing it for 24 hours, curing it for 7 days under plastic sheets, and then letting it dry for 3 days at room temperature. For pre-treated coir fibres, the same procedure was used. The findings demonstrated that coir fibre composites have the right mechanical and thermal characteristics to be used as ceiling tiles.Furthermore, a pull-out test was conducted to elaborate on the cement-fiber interaction. Better cement contact and reduced sliding behaviour are provided by pre-treated fibres compared to untreated coir fibre. The interaction between the washed and unwashed fibres is also enhanced because unwanted elements have been eliminated.

[27] offered a thorough examination of the compressive behaviour of concrete that was limited using an inexpensive polymer reinforced with natural fibres. Uniaxial compression tests were used to assess concrete cylinders enclosed with hemp, jute, and cotton fibres. The study showed that natural fibre polymers successfully increased concrete's ductility and compressive strength; for example, jute, hemp, and cotton polymers showed strength increases of 42%, 25%, and 28%, respectively. The results highlight how natural polymers, especially jute polymer, can be used to improve the confinement effect of concrete.

[28] looked into how reinforced concrete (RC) beams may be strengthened in flexure by using kenaf fiber-reinforced polymer (KFRP). Two RC beams, each 1860 x 240 x 125 mm, were put to the test: one was laminated with KFRP, while the other was used as a control beam. The outcomes showed how well natural polymer composites, like KFRP, strengthen reinforced concrete beams. The strengthened beam deflected 43% less than the control beam at the control beam's yield load, demonstrating the considerable reduction in beam deflections caused by the KFRP laminate under equivalent pressures.

[29] evaluated the suitability of five slabs reinforced with two natural fibers—jute and coir—as cost-effective strengthening materials by conducting an experimental investigation of them under uniformly distributed load using two configurations, strip and square, aided by a load spreader. The fibres' resistance to moisture and burning was assessed by functional experiments, such as fire flow tests and fibre moisture absorption tests. According to the findings, coir fiber-reinforced polymer concrete (CFRPC) outperformed jute fiber-reinforced polymer concrete (JFRPC), as jute's finer fibre structure led to less efficacy.In addition to burning faster than CFRPC, JFRPC absorbed water a little more intensely. Using a simply supported square slab subjected to a uniformly distributed load, a flexural test was conducted to assess the flexural properties with and without strengthening using natural fibre composites, simulating real-world conditions. The percentage improvements in the ultimate load-carrying capacity and cracking load-carrying capacity of reinforced slabs were both higher than those of the control specimen, ranging from 15.03 to 37.25% and 6.67 to 33.33%, respectively.Slabs didn't collapse in flexure until they started to crack. Overall performance indicates that natural fibre slabs outperform control slabs when subjected to flexural loads.

The effects of both treated and untreated coconut fibres in self-compacting concrete (SCC) are discussed by [30]. The mechanical, chemical, and physical properties were determined by the testing. Three different methods were used in the study to treat the fibre: soaking, boiling, and chemical treatment. Using SEM analysis, the microstructure of the mixes made with and without treatments was understood. As compared to control mixtures, soaked fibres exhibited better tensile strength (20.37%), greater flexure strength (12.5%), and a little lower compressive strength (around 2.71%).

The improved mechanical properties of boiling fibres have been attributed to their stronger coupling. It showed increases in tensile strength of 36.86 percent, flexural strength of 12.50 percent, and compressive strength of 23.48 percent when compared to control mixes. Compressive strength rose 51.8%, tensile strength rose 44.13%, and flexure strength rose 37.5% when chemically treated fibre was compared to control blends. According to strength measurements, chemically treated material performs better than the other.To improve the mechanical properties of the specimen, 1% of chemically treated coir fibre is the ideal amount to use. Compared to conventional concrete, coir fibre reinforced polymer composites have a higher compressive strength, according to the literature review. Less than 1% is the optimal fibre dosage for the test participant. The specimen is more resistant to fracture when natural fibre polymer is used.

[31] Assessed how fibre length affected the mechanical and physical characteristics of albumin cement compounds improved with coconut fibre. Coconut fibres of different lengths (2.5 mm, 5 mm, 10 mm, and 20 mm) were added to the mixture in part to replace the cement, and albumin protein was utilised as a binder. Bending resistance, compressive strength, apparent density, moisture content, and water absorption were all evaluated by testing. The findings showed that

while adding longer fibres improves bending strength, they also decrease process ability by forming low-density holes, which raises moisture content and water absorption capacity.

[32] investigated how natural fibres behaved in concrete buildings, emphasising coconut fibre as a resilient fiber-based composite because of its distinct mechanical qualities in contrast to rayon. To avoid moisture impacts when utilised in concrete, they coated coconut fibre with natural latex in their investigation. Over the course of a 28-day experiment, concrete's compressive and tensile strengths were assessed using different coconut fibre percentages (e.g., 0.5%, 0.75%, and 1%) and fibre lengths (20 mm, 25 mm, and 30 mm). Because of their sustainability and local availability, the results showed that natural fibres, such as coconut fibre, enhance the mechanical qualities of concrete and ought to be promoted in civil engineering.

After treating the coconut fibres with 5% NaOH, Abdul [33] examined the mechanical behaviour of coconut fibres of different lengths (5 mm, 10 mm, and 15 mm) reinforced with epoxy resin. The samples were placed by hand and tested using a Universal Testing Machine (UTM) in compliance with ASTM D3039 standards. The study found that the composite material's tensile qualities, ductility, and hardness are improved by NaOH treatment. The findings also demonstrated that tensile strength increases with fibre length, with 15 mm coconut fibres showing the highest tensile strength.

The application of coconut fibre in concrete structures was the subject of a behavioural study by [34]. Because of its strong adhesion, their research showed that adding coconut fibre to concrete enhances a number of its technical qualities. Before the coconut fibre was added to the concrete mix, it was treated with natural latex to improve its performance.
The concrete's moisture content has no effect there. Concrete can have its tensile, bending, and compression strengths increased by adding coconut fibre. An ideal fibre level, according to the study, is between 1% and 2% to 3% of cement weight. For concrete cubes of grades M25 and M30, the compressive strength was assessed after seven, fourteen, and twenty-eight days. Because coconut fibre is organic and offers superior western fibre management, the results show that coconut and coconut concerts can be used in building.

III. MATERIALS AND METHODOLOGY

A. Constituent Materials

Cement

Ordinary Portland Cement (OPC), specifically Dangote Cement, was used in this study. The cement was procured from a reputable local distributor in Uli, Anambra State, Nigeria. Dangote Cement is renowned for its superior quality, meeting the requirements of the Nigerian Industrial Standards (NIS 444-1:2003) and other relevant international standards such as ASTM C150. This ensures the necessary strength, consistency, and durability of the concrete mix.

Fine Aggregate

River sand was used as the fine aggregate in this study. It was extracted from the riverbank in Onitsha, Anambra State, Nigeria. The sand was free from harmful substances and organic contaminants, making it suitable for concrete production. To achieve a uniform particle size distribution, the sand was passed through a 4.75 mm sieve. River sand was chosen due to its natural grading, which enhances the workability and bonding properties of the concrete mix.

Coarse Aggregate

Chippings were supplied from a local source in Uli, Anambra State, near the Timber Market. The chippings were thoroughly graded and carefully washed to remove dust and clay particles. The aggregate size ranged from 10 mm to 20 mm, conforming to the specifications for coarse aggregates as outlined in BS 882 for use in concrete production.

Oil Palm Fiber

In Oba, Anambra State, Nigeria, oil palm fibers were obtained as by-products of oil palm processing operations. The extraction and preparation process involved the following steps:

1. Purchasing

Fresh oil palm bunches were sourced from local farms in Oba, a region known for its abundance of oil palm plantations.

2. Extracting

The fibers were manually peeled from the outer layers of the palm fruit bunches using a traditional method. This process involved separating the fibrous strands from the residual pulp. To soften the fibers and facilitate the separation of individual strands, the extracted fibers were soaked in water for 24 hours.

3. Drying

The soaked fibers were sun-dried for 48 hours to remove excess moisture. This drying process was crucial to prevent microbial growth and degradation, ensuring the fibers remained suitable for use.

4.Preparation
Once dried, the fibers were cut into lengths of approximately 25–25 mm to be used as an additive in the concrete mix.
Portable Water
Clean portable water was obtained from a tap located within the Civil Engineering Laboratory at COOU, Uli Campus, Anambra State, Nigeria. The water was free from pollutants, making it suitable for mixing and curing concrete. The quality of water used in concrete production is crucial to avoiding adverse chemical reactions that could compromise the structural integrity of the concrete.

B. Methodology
Sieve Analysis
Sieve analysis determines the particle size distribution of aggregates by measuring the material retained on a series of sieves. This process evaluates the gradation of fine and coarse aggregates to optimize concrete's workability, compaction, and strength. Aggregates are dried, weighed, mechanically sieved, and the percentage of material retained and passing is calculated.

Slump Test
The slump test evaluates the workability of fresh concrete by observing its vertical settlement, or slump, after a standard cone-shaped mold is removed. This test ensures the concrete mix has the correct consistency for compaction and placement. Concrete is layered into the cone, tamped, and then the cone is carefully lifted to measure the height difference between the slumped concrete and the mold.

Compressive Test
The compressive strength test measures a concrete specimen's resistance to crushing by determining the maximum compressive load it can withstand. Concrete cubes (150 mm × 150 mm × 150 mm) are cast, compacted, and cured at 20°C ± 2°C for 7 to 28 days before being tested in a compression machine. The load is applied gradually until failure, and compressive strength is calculated using the formula:
Compressive Strength = Maximum Load at Failure / Cross-sectional Area.

Tensile Test
The tensile strength test evaluates concrete's resistance to cracking under tension. Cylindrical specimens (150 mm × 300 mm) are cured for 7 to 28 days and tested using the split tensile method until failure. Tensile strength is calculated using the formula:
Tensile Strength = (2 × Maximum Load) / (π × Diameter × Length).
The results determine the concrete's structural performance.

IV. RESULTS AND DISCUSSION

The indicated samples were subjected to the tests outlined below.
A. Sieve Analysis Test (Particle Size Distribution Test)

Table 1: Sieve Analysis Test Data

Sieve Size (mm)	Weight of Sand Retained (kg)	Weight of Steve (kg)	Percentage Retained (%)	Cumulative Percentage Retained (%)	Cumulative Percentage Passing (%)
8	0.40	0.30	6.67	6.67	93.33
10	0.35	0.30	3.33	10.00	90.00
12	0.35	0.30	3.33	13.33	86.67
20	0.70	0.30	20.00	33.33	66.67
30	0.55	0.30	16.67	50.00	50,00
40	0.60	0.30	20.00	70.00	30,00
80	0.70	0.30	26.67	96.67	3.33
Pan	0.30	0.30	0,00	96,67	3.33

B. Slump test

The Slump Test was conducted to evaluate the workability of concrete mixes with varying fiber percentages, focusing on their fluidity and consistency to ensure proper compaction and ease of placement. The results, presented in Table 2, illustrate the impact of fiber addition on the concrete's workability.

Table 2: Slump test

Percentageof Additive (%)	Trial	Slump Value (mm)	Height of Cone (mm)	Water-Cement Ratio
0.0	1	150	300	0.7
0.5	1	120	300	0.7
1.0	1	100	300	0.7
1.5	1	60	300	0.7

C. Compressive Strength Test

Compressive strength tests were conducted on concrete samples with varying fiber percentages at 7, 14, 21, and 28 days of curing to evaluate strength development. The results in Table 3 show the impact of fiber addition on the concrete's strength.

Table 3: Compressive Strength Test Results

Additive (%)	7 Days (N/mm^2)	14 Days (N/mm^2)	21 Days (N/mm^2)	28 Days (N/mm^2)
0.0	16.25	14.70	14.30	17.70
0.5	15.35	15.20	13.45	15.85
1.0	11.60	12.95	14.10	13.30
1.5	13.05	15.10	14.00	11.55

D. Tensile Strength Test

Tensile strength tests measured the impact of coconut fiber percentages on concrete at 7, 14, and 28 days. Results in Table 4 highlight fiber effects on tensile resistance.

Table 4.4: Tensile Strength Test

Additive (%)	7 Days (N/mm^2)	14 Days (N/mm^2)	21 Days (N/mm^2)	28 Days (N/mm^2)
0.0	2.50	2.85	3.00	3.25
0.5	2.70	3.10	3.30	3.50
1.0	2.40	2.90	3.10	3.25
1.5	2.30	2.75	3.00	3.15

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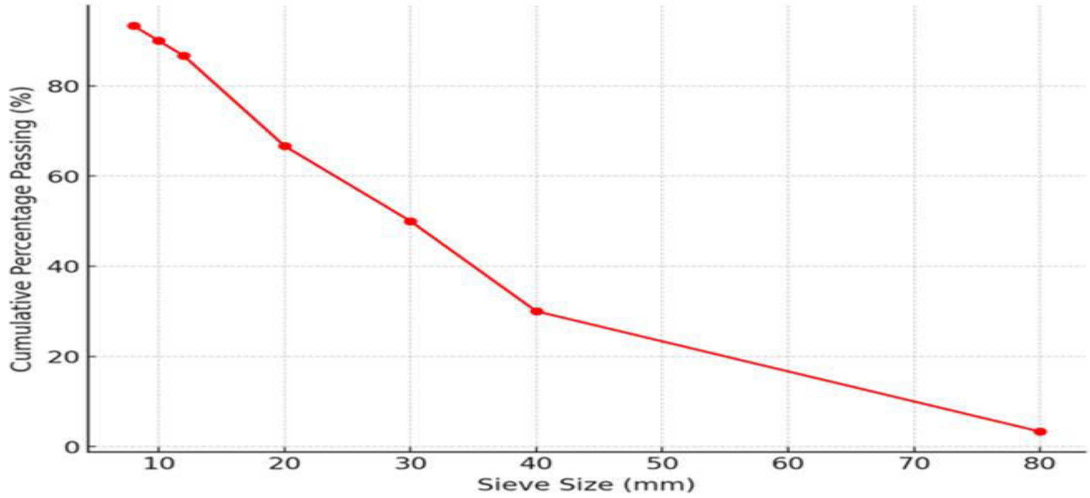

Fig. 1: Sieve Analysis Graph

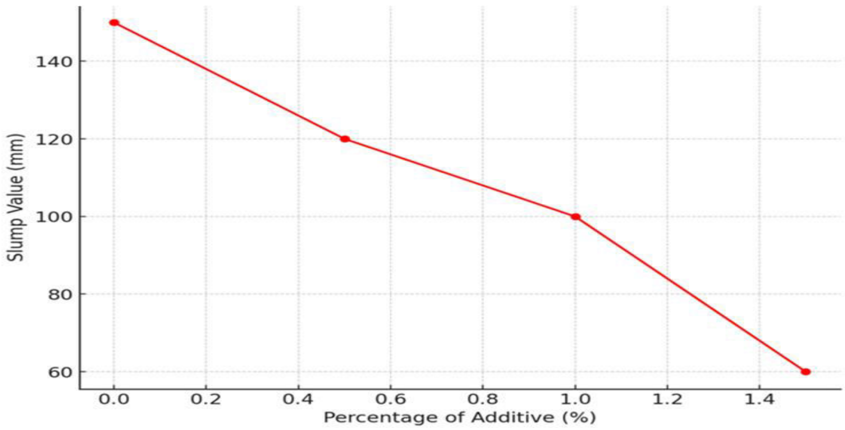

Fig. 2: slump test result

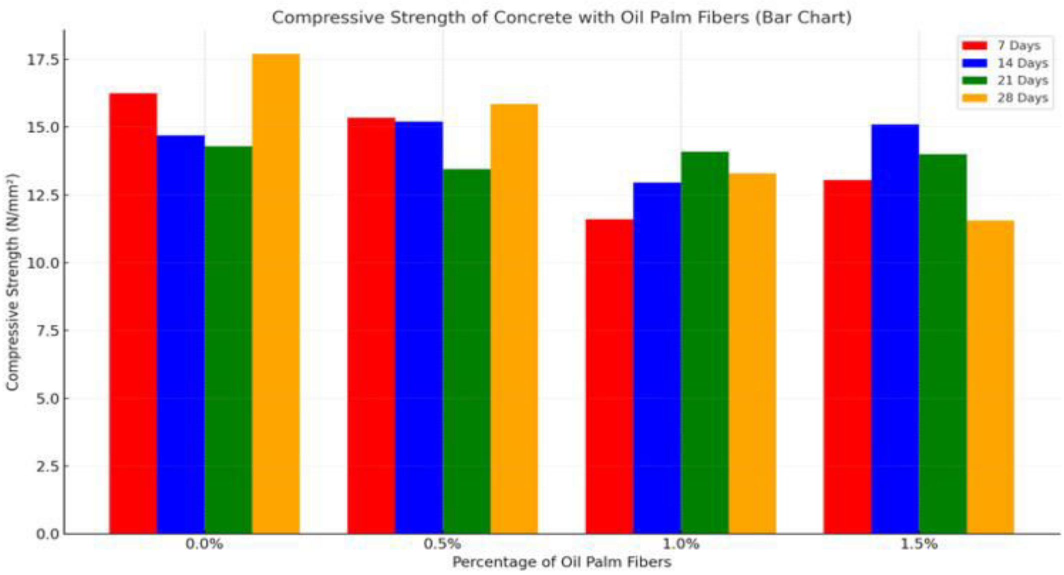

Fig. 3: Compressive Strength at Different Ages

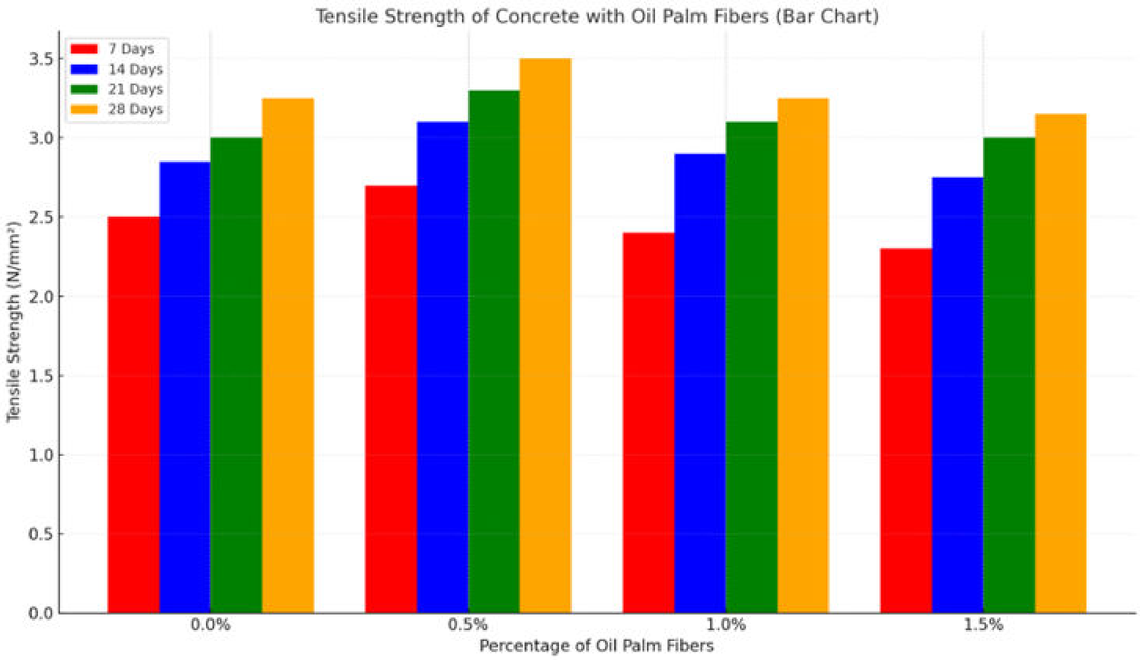

Fig. 4: Tensile Strength test at different ages

V. CONCLUSION AND RECOMMENDATION

5.1 Conclusion

This study evaluated the effects of oil palm fibers at 0.0%, 0.5%, 1.0%, and 1.5% concentrations on the compressive and tensile strength of concrete over 7, 14, 21, and 28 days of curing.

1. Compressive Strength: A 0.5% fiber mix achieved the best strength-to-durability ratio, while higher fiber contents reduced performance due to void formation.
2. Tensile Strength: The 0.5% fiber mix exhibited the highest tensile strength, with minimal improvements observed at higher fiber contents.
3. Practical Use: Moderate fiber content (0.5%) enhances durability and crack resistance, making it suitable for structural and non-structural applications.

Oil palm fibers provide a sustainable, eco-friendly solution to improving concrete performance when used with proper mix design.

5.2 Recommendations

1. Use 0.5% fiber for optimal strength and durability.
2. Extend curing for mixes with higher fiber content.
3. Apply fibers in pavements, slabs, and non-structural elements.
4. Investigate long-term performance, flexural strength, and cost feasibility.

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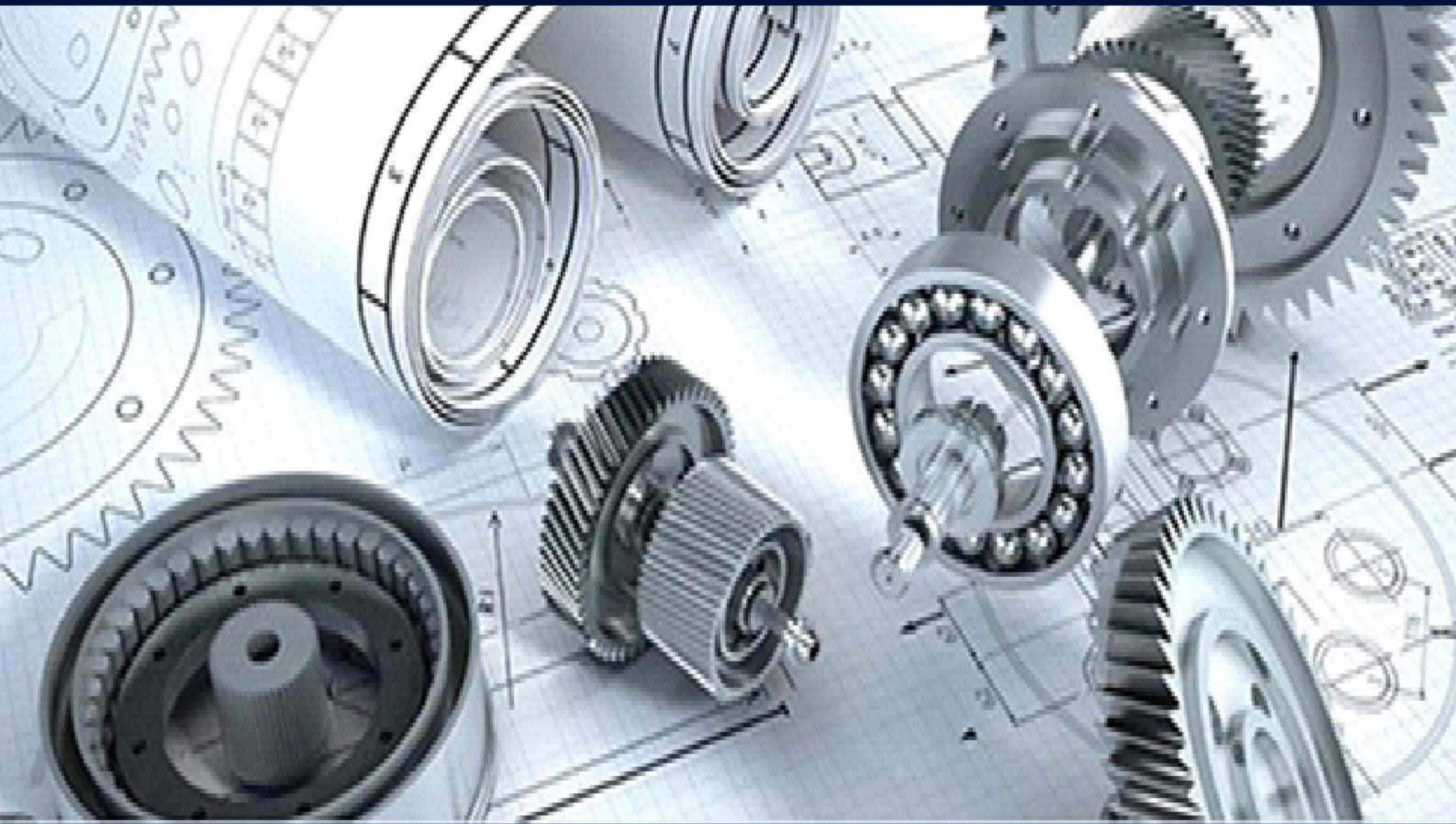

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