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THE USE OF OIL PALM FIBER AS AN ADDITIVE MATERIAL IN CONCRETE

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Abstract: The incorporation of oil palm fiber (OPF) as an additive material in concrete presents a sustainable approach to improving mechanical properties while reducing agricultural waste. OPF, a byproduct of the palm oil industry, has shown potential in enhancing tensile strength, ductility and crack resistance, making it a viable alternative reinforcement material. This study examines the effects of OPF on the compressive strength, tensile strength, workability, and durability of concrete. The findings indicate that OPF improves tensile strength by bridging microcracks and increasing energy absorption capacity, which enhances the material's resistance to dynamic loads. However, its effect on compressive strength varies, as excessive fiber content may introduce voids and reduce density, leading to a slight decrease in compressive strength. The presence of OPF also affects workability, requiring adjustments in mix design through the use of superplasticizers or optimized water-to-cement ratios. Additionally, OPF-modified concrete demonstrates improved durability by reducing shrinkage and increasing resistance to cracking.

The study highlights the potential of OPF as an environmentally friendly and cost-effective reinforcement material in concrete, contributing to sustainable construction practices while addressing waste management challenges. Further research is recommended to refine mix proportions and assess long-term performance in different environmental conditions to ensure practical implementation in structural applications.

Keywords - Dynamic loads, Waste management challenges

INTRODUCTION

Concrete is one of the most widely used construction materials worldwide due to its high compressive strength, durability and versatility in various structural applications. However, its inherent brittleness and low tensile strength make it prone to cracking and failure under tensile and impact loads. To overcome these limitations, reinforcement materials such as steel bars, synthetic fibers, and other additives are commonly incorporated into concrete to enhance its mechanical properties. While conventional reinforcement methods have proven effective, they often come with high costs and environmental concerns related to material production, resource depletion, and carbon emissions. As a result, researchers and engineers have been exploring sustainable alternatives, particularly the use of natural fibers, as an eco-friendly and cost-effective solution for improving concrete performance.

Oil palm fiber (OPF), an abundant byproduct of the palm oil industry, has gained attention as a potential reinforcement material in concrete due to its unique mechanical and physical properties. OPF is a lignocellulosic fiber with high tensile strength, flexibility, and resistance to biodegradation, making it a viable alternative for enhancing the structural integrity of concrete. The incorporation of OPF in concrete has been found to improve tensile strength by acting as a bridging mechanism that restricts the propagation of microcracks, leading to increased ductility and impact resistance. Additionally, OPF can contribute to better energy absorption capacity, making concrete more resilient to dynamic and flexural loads. However, while OPF has demonstrated significant advantages in improving tensile properties, its effect on compressive strength remains a subject of investigation. Some studies indicate that the presence of OPF can slightly reduce compressive strength due to increased porosity and void formation, particularly when excessive fiber content is used. Therefore, optimizing the OPF dosage and distribution within the concrete matrix is essential to balancing its benefits and minimizing any adverse effects.

Another critical aspect of OPF-modified concrete is its workability and durability. The inclusion of natural fibers tends to reduce concrete workability due to increased water absorption and fiber entanglement, which can affect the ease of mixing, placing, and finishing. To mitigate this issue, adjustments in mix design, such as the use of superplasticizers, fiber treatment methods, and optimized water-to-cement ratios, are necessary to ensure uniform fiber dispersion and adequate flowability. In terms of durability, OPF-modified concrete has shown potential in reducing shrinkage and cracking by improving stress distribution, which can contribute to a longer service life and lower maintenance costs. Furthermore, utilizing OPF in concrete promotes sustainable construction practices by repurposing agricultural waste, reducing landfill accumulation, and lowering the overall carbon footprint of building materials.

Despite its promising advantages, the practical application of OPF in concrete requires further research to establish standardized mix proportions, evaluate long-term performance under various environmental conditions, and address potential challenges related to fiber degradation and compatibility with cementitious materials. This study aims to provide a comprehensive evaluation of OPF as an additive material in concrete, focusing on its effects on compressive strength, tensile strength, workability, and durability. By understanding the influence of OPF on concrete properties, this research contributes to the development of sustainable and high-performance construction materials that align with global efforts toward environmental conservation and waste management.

SCOPE AND PURPOSE

The use of oil palm fiber (OPF) as an additive in concrete presents a sustainable and innovative approach to improving the performance and environmental profile of construction materials. As a byproduct of the palm oil industry, OPF is abundantly available in many tropical regions, particularly in countries like Malaysia, Indonesia, and parts of Africa. Rather than disposing of this agricultural waste, it can be processed and incorporated into concrete to enhance its properties while addressing environmental concerns related to waste management. The inclusion of oil palm fibers in concrete mixtures has been shown to improve key mechanical characteristics such as tensile strength, flexural strength, impact resistance, and ductility. These fibers help bridge cracks that form during the curing and loading of concrete, thus improving its toughness and extending its service life.

CONSTITUENT COMPONENT

A – Cement

A cement is a binder, a substance that sets and hardens and can bind other materials together. Ordinary Portland Cement is a substance used for construction purposes. Cement is seldom used on its own, but rather to bind sand and gravel (aggregate) together. Cement mixed with fine aggregate produces mortar for masonry, or with sand and gravel, produces concrete ordinary Portland cement of 53 grade is used.

Table 1. Cement Characteristics.

Test	Results
Specific gravity	3.03
Consistency	34%
Fineness	8%
Initial setting time	76min
Final setting time	248min

B – Sand And Gravel

Sand and gravel are essential components in concrete, each playing a specific role in achieving strength and workability. Sand, which acts as the fine aggregate, is a natural granular material composed of finely divided rock and mineral particles, with most passing through a 2 mm sieve for bituminous concrete or a 4.75 mm sieve for Portland cement. It is free from clay, silt, and organic impurities, and its physical characteristics are specified in IS:2386-1963. Sand helps fill the voids between gravel particles and improves the overall workability of the mix. Gravel, used as the coarse aggregate, includes larger particles such as crushed stone, slag, recycled concrete, and natural stones, all retained on a 4.75 mm sieve and passing through a 3-inch screen. The size of gravel used depends on the type of construction, and where possible, sizes above 20 mm can be used. Well-graded, cubical or rounded gravel with consistent shape and size is preferred, and it must be clean and dust-free to ensure proper bonding and long-term durability in concrete.

Table 2. Properties of fine and coarse aggregates.

Test	Sand	Coarse aggregate
Specific gravity	2.48	2.84
Fineness modulus	3.861	4.576
Water absorption	2.73%	0.35%

C – Water

Water is used in the experimental work is conformed to is: 456-2000 for mixing as well as curing of concrete specimens. Combining water with a cementations material form a cement paste by the process of hydration. The cement paste glues the aggregate together, fills voids within it, and makes it flow more freely. Lower water to concrete ratio will yield a stronger, more durable concrete; while more water will give a free-flowing concrete with a higher slump. Impure water is not taken to make concrete can cause problems when setting over in causing pre mature failure of the structure. Hydration involves many different reactions, often occurring at the same time. The pH value should not be less than 7.

D – Oil Palm Fiber

Oil palm fiber (OPF) is a natural agricultural byproduct derived from the oil palm tree (Elaeis guineensis), which is primarily cultivated for its fruit and palm oil production. This fiber is obtained during the processing of oil palm fruit, where it is separated from the fruit flesh and kernel. Oil palm fiber is abundant, biodegradable, and environmentally friendly, making it an attractive material for various applications, particularly in the construction industry.In recent years, OPF has gained popularity as an additive in concrete and other building materials. Its inclusion in concrete mixes can enhance various properties, such as tensile strength, durability, and resistance to cracking. The fibrous structure of OPF helps improve the bonding between the cement matrix and aggregates, thus contributing to the overall mechanical performance of the concrete.

E – Admixer

Armix Ellecrete PC 5 is a Plasticizing, water reducing PCE based concrete admixture for regular grade of concrete. In this admixture is to produce high workability concrete requiring little vibration during placing. And also increased strength, higher cohesion, chloride free. For normal grades of concrete a dosage from 0.4% to 1.0% by weight of cement is recommended. The dosage may increase to 1.5% to achieve specific slump requirement.

METHEDOLOGY

1 – Material collection

In concrete projects involving oil palm fiber (OPF) as an additive, the careful collection of materials is vital to achieving quality results. OPF should be sourced in a clean, dry state from local palm oil mills, ensuring it is free from oils, dust, and other impurities that can hinder bonding with the cement. The cement used should be high-quality Portland cement obtained from reputed suppliers. Fine and coarse aggregates (such as sand and gravel) must also be sourced from trusted vendors or local quarries and must be clean and well-graded to ensure uniform mixing and structural integrity. Potable water is essential for mixing to avoid chemical contamination, and admixtures like superplasticizers or retarders may be added to enhance the performance characteristics of the mix. Accurate measuring equipment must be used for proportioning, and safety protocols should be followed during handling and mixing. Proper documentation and quality checks during material collection help improve the strength, durability, and sustainability of the concrete.

2 – Material testing

Preliminary testing of all materials is conducted to ensure they meet the required standards. Aggregates are subjected to sieve analysis to determine particle size distribution and water absorption tests to assess porosity. Coarse aggregates are tested using the wire basket method. Cement is tested for normal consistency, setting time, specific gravity using Le Chatelier's apparatus, and fineness. Fine aggregates undergo sieve analysis and specific gravity tests using the pycnometer. These tests help verify the quality of raw materials and ensure their suitability for concrete production with OPF.

3 – Preparation of specimens

The preparation of concrete specimens with OPF involves several important steps to ensure uniform distribution and optimal mechanical behavior. First, the oil palm fibers are collected, thoroughly cleaned, and dried to remove any impurities. The fibers are then cut into specific lengths (typically between 10 mm and 50 mm) based on research suggesting that certain lengths enhance tensile and flexural strength. These treated fibers are uniformly mixed into the concrete matrix to ensure they are properly dispersed and do not clump. Accurate batching and consistent mixing techniques are followed to create test specimens that reflect realistic performance under various load conditions.

4 – Testing of specimens

Testing of OPF-reinforced concrete specimens is performed to evaluate their mechanical, durability, and performance properties. After curing, the specimens undergo a series of tests to assess compressive strength, tensile strength, and flexural strength. The compressive strength test (usually on cube or cylinder specimens) helps determine the concrete's capacity to bear loads without failure, giving insight into its structural application potential.

Tensile and flexural strength tests evaluate the concrete's resistance to cracking and bending. These tests are crucial because OPF enhances the post-cracking behavior of concrete, improving its toughness and flexibility. This makes OPF-reinforced concrete particularly beneficial for structures where impact resistance and ductility are important. Overall, these evaluations help understand how oil palm fiber contributes to the durability and load-bearing capacity of concrete.

RESULT AND DISCUSSION

Table 3: Compressive strength result

Mix design	OPF	Compressive strength (N/mm^2)	
		7^{th} day	28^{th} day
MF0	0%	16.8	28
MF15	15%	23.2	28.8
MF20	20%	26.7	33.15
MF25	25%	28.9	38

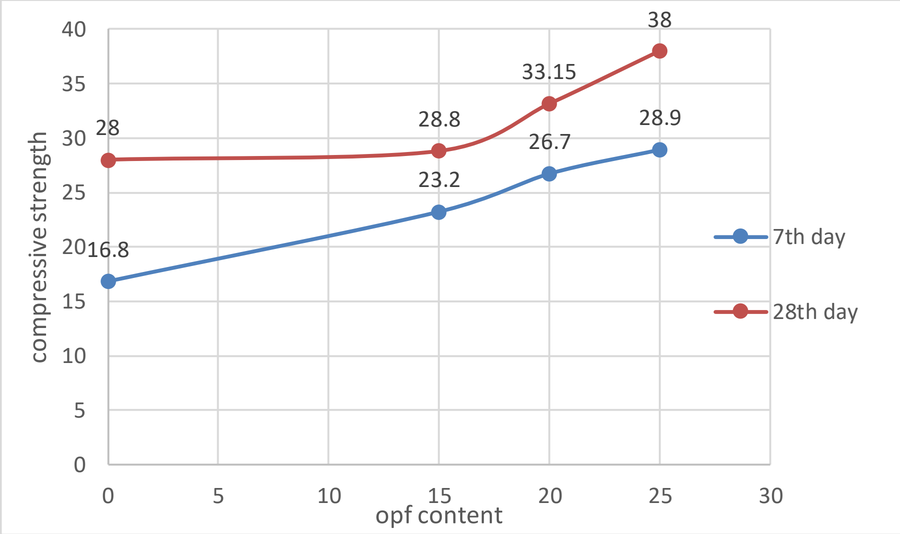

Fig. 1. Compressive strength at 7 and 28 days at N/mm ^{2}

Table 4: Slump value

Mix design	OPF	Workability (mm)	Type of slump
MF0	-	15	True slump
MF15	15%	10	True slump
MF20	20%	9.8	True slump
MF25	25%	9.4	True slump

Table 5: Compaction factor

Mix design	OPF	Compaction factor
MF0	-	0.89
MF15	15%	0.8
MF20	20%	0.73
MF25	25%	0.71

Table 6: Split tensile strength result

Mix design	OPF	Tensile strength(N/mm²)	
		7th day	28th day
MF0	0%	1.7	2.69
MF15	15%	2.47	2.82
MF20	20%	2.52	3.13
MF25	25%	2.74	3.4

Fig. 2. Split tensile strength at 7 days & 28 days

Table 7: Water absorption test result

Mix design	OPF	Water absorption
MF0	-	2.5
MF15	15%	2.37
MF20	20%	2.23
MF25	25%	2.11

DISCUSSION

The slump test results clearly indicate a reduction in workability when Oil Palm Fiber (OPF) is added to concrete. The conventional mix had a slump value of 15 mm, whereas the mix with 25% OPF showed a reduced slump of 9.4 mm. This reduction reflects that the mixture becomes less fluid and more difficult to place or compact. The fibrous texture of OPF tends to absorb more water and restricts the flow of the mix, leading to stiffer and less workable concrete.

The compaction factor test further supports the observation from the slump test. The compaction factor dropped from 0.89 in conventional concrete to 0.71 in concrete with 25% OPF. A lower compaction factor indicates that more effort is needed to compact the concrete, again pointing to reduced workability due to the presence of OPF. The fibers increase internal friction within the mix, making it harder to achieve full compaction without mechanical effort.

Despite the reduction in workability, the addition of OPF significantly enhanced the strength properties of the concrete. The compressive strength increased from 28 N/mm² in conventional concrete to 38 N/mm² with 25% OPF. This improvement shows that OPF acts as a strengthening component, likely due to better bonding within the concrete matrix and the bridging effect of the fibers, which help control crack propagation.

Similarly, the split tensile strength also showed a positive improvement with the inclusion of OPF. The strength increased from 2.69 N/mm² to 3.4 N/mm². This suggests that OPF contributes to better tensile resistance, which is crucial for preventing cracks and improving the overall ductility of the concrete structure.

Water absorption slightly decreased with the addition of OPF, going from 2.5% in conventional concrete to 2.11% with 25% OPF. This reduction indicates that the concrete became denser and less porous. Lower water absorption is beneficial as it enhances durability by reducing the ingress of harmful substances like chlorides and sulfates. In summary, while OPF negatively impacts the workability of fresh concrete, it significantly improves the strength and durability characteristics of hardened concrete. These findings suggest that OPF can be a valuable additive in structural concrete, especially where strength and long-term performance are prioritized over ease of handling.

CONCLUSION

The workability and compressive strength of OPF concrete were compared with plain concrete (control specimen) through slump test and compression test. Oil Palm Fiber (OPF) to concrete mixtures had a noticeable effect on the workability of the fresh concrete. Specifically, as the percentage of OPF in the mixture increased, the workability decreased. This reduction in workability was observed through a slump test, which showed that higher amounts of OPF made the concrete mixture less fluid and more difficult to work with. The relationship between the amount of OPF added and the reduction in workability was directly proportional. In terms of compressive strength, the study revealed that the inclusion of OPF positively impacted the hardened concrete's performance. At all ages tested, the concrete with OPF exhibited higher compressive strength compared to plain concrete. Moreover, the enhancement in compressive strength was linear, meaning that as the amount of OPF increased (15%, 20%, and 25%), the compressive strength consistently improved. This trend was particularly evident at the mature age of 28 days, suggesting that OPF can significantly strengthen the concrete over time.

Despite these findings, the study did not determine an optimum content of OPF for maximizing compressive strength. However, the data from the slump test and the fresh density measurements of OPF concrete can help in identifying practical limits for OPF addition. This implies that while OPF can enhance compressive strength, it is also essential to consider its effect on workability and fresh density to achieve a balanced and efficient concrete mixture

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