COMPARATIVE STUDY OF NYLON FIBER REINFORCED CONCRETE WITH PCC FOR COMPRESSIVE STRENGTH AND WORKABILITY

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Abstract- The influence of nylon fiber addition on the workability and compressive strength of concrete is studied in this investigation. Two concrete mixes, Plain Cement Concrete (PCC) and Nylon Fiber Reinforced Concrete (NFRC), were prepared using Ordinary Portland Cement (OPC), fine sand, crushed granite aggregates, potable water, and synthetic nylon fibers 50 mm long. NFRC mix included nylon fibers at 3% of cement weight by weight with a mix proportion of 1:4:2 A higher proportion of fine aggregates mix helps create a denser matrix and improves fiber bonding and a water-cement proportion of 0.6, whereas PCC used a traditional 1:2:4 proportion with a 0.5 water-cement proportion. The tests were conducted on fresh concrete according to standard slump and temperature tests, as well as compressive strength tests after 28 days of water curing in accordance with ASTM standards. Results showed that NFRC recorded a greater slump in value (190 mm) than that of PCC (150 mm), proving better workability. NFRC indicated slightly lower mean compressive strength (7.07 MPa) than PCC (9.05 MPa) due to possible increased water content and fiber hindrance in compaction. Even with a decrease in strength, NFRC had less variability and was more consistent. These results indicate that NFRC is ideal for non-structural uses with improved workability and resistance to cracking like pavements, overlays, and precast components where ductility and toughness take precedence over maximum compressive strength.

Keywords- Nylon Fiber, Compressive Strength, Durability, Mix Design, Sustainability

1 Introduction

Concrete is a widely applied construction and civil engineering material because of its cost-effectiveness and high strength in compression. Fiber-reinforced concrete has been used widely across many structures over the past decades in engineering. Recent research hints at expanded applications of fiber-reinforced concrete and attempts to mimic its mechanical behavior with assistance from sophisticated tools such as the Lattice Discrete Particle Model [1,2]. Lightweight foamed concrete (LFC) has been of interest as a green material for semi-structural purposes based on its low density and environmental advantages. Its limited durability and low mechanical strength have limited its broader application in structural members. Recent research has been aimed at optimizing LFC performance through fiber reinforcement, especially with hybrid mixes such as nylon and polypropylene fibers [3]. This research explores the use of Ground Nut Shell Ash, Cashew Nut Shell Ash, and Discarded Nylon Fiber in cement concrete to make it more sustainable. It compares the mechanical behavior of such green composites as a possible substitute for regular concrete [4]. Based on limited experimental data, e.g., polypropylene and steel fiber combinations compression and bending tests, the model simulates and examines significant mechanical responses and parameter sensitivities [5]. Nylon fibers (NF) improve concrete by increasing compressive strength, and overall durability. Experiments indicate that the inclusion of 0.1% NF and 5%

eggshell powder in self-compacting concrete improves compressive and tensile strength by 6% and 4%, respectively [6]. Past studies have considered the incorporation of nylon fibers to improve concrete's mechanical properties, specifically its tensile and compressive strength. Different lengths of fibers have indicated significant impacts, with (25 mm, 50 mm and 75 mm) fibers reporting the best outcomes [7] The increasing demand for concrete has resulted in excessive exploitation of natural sand, especially river sand, and hence severe environmental degradation. The current study investigates a sustainable option through the use of stone dust (SD) as a partial substitution of fine aggregate and nylon fiber (NF) as reinforcing material in concrete to assess their combined impact on compressive and splitting tensile strengths employing artificial neural network (ANN) modeling [8].

Nylon Fiber reduces micro-cracking and enhances post-crack behavior. Machine learning models were able to predict concrete performance. SCC quality was unaffected despite reduced workability with optimized fiber. This blend provides a sustainable solution in order to improve concrete performance in contemporary construction [9]. This research examines the impact of nylon fibers (1% to 2.5% by volume) on compressive and splitting tensile strength of concrete. Results showed that strength and toughness in nylon fiber reinforced concrete were improved, and 2.5% of fiber content showed optimal performance. 28 days of water curing gave maximum compressive strength of 36.62 MPa and splitting tensile strength of 5.10 MPa. Such results make nylon fiber a potential candidate to be utilized as an additive in order to enhance mechanical characteristics of concrete [2]. The study provides the reliable early damage detection under cyclic loading, which results in enhanced durability and safety of FRC structures [10]. By utilizing the two fibers, they produced Hybrid Nylon-Steel Fiber Reinforced Concrete with significant compressive strength of 101.25 MPa with Kings-Scheffe's (6,2) model [11]. Migrated to the imperatives of affordable and sustainable substitutes to steel, this research investigates the utilization of bamboo strips and nylon fibers for reinforcing light wall panels with strength, deformation, and fire resistance. In comparison to existing studies on single-material reinforcements, this hybrid method presents better performance; more research is suggested on long-term durability and applicability at a larger scale [12]. With increasing environmental concerns and resource scarcity, this research explores how nylon fiber can be used to increase the compressive strength of concrete using Crushed Stone Dust (CSD) as a green substitute. On optimization using RSM, it shows better strength with the addition of nylon fiber, consistent with previous work but with a better accurate mix design; however, the workability deterioration emphasizes the requirement for balancing performance and practicality in upcoming applications [13].

In this Hybrid Nylon-Fiber Reinforced Concrete and Recycled Nylon Fiber Fabric Concrete Concretes possess greater compressive strength and energy absorption than plain concrete. NFFRC was better than PC and NFRC, with improvement in compressive strength of 5.37% and 10.74%, respectively. These results indicate that recycled nylon fibers can be effective as an alternative in structural application [13,14]. Fibers are secondary reinforcement materials that function as crack arresters, which greatly enhance the static and dynamic characteristics of concrete. The response of fiber reinforced concrete depends on the type of fiber and the aspect ratio. Extensive research and development have been conducted since the 1960s, and this has resulted in a broad range of FRC products with improved mechanical behavior [15,16]. Plain concrete suffers from low tensile strength and a high environmental impact due to its carbon footprint. The combined use of fibers and recycled materials offers a promising solution to enhance concrete's mechanical and durability performance. This study explores the synergistic effects of silica fume and nylon fibers on recycled aggregate concrete to develop a more sustainable and durable construction material [18]. Optimize the compressive strength of Hybrid Polypropylene–Nylon Fiber Reinforced Concrete. 112 mix ratio samples attained a maximum compressive strength of 71.36 MPa, which was superior to previous models and the standard requirement. Consistent findings are that a combination of fibers enhances the quality of the concrete for high-strength applications [19]. This study explores nylon fiber in addition to enhance compressive strength and durability, showing peak performance at 1.5% fiber content. Compared to previous studies, it confirms fiber effectiveness in improving strength and resistance, though it highlights a trade-off with workability requiring careful mix design adjustments [20]. To overcome the inefficiencies of trial-based mix design, this study applies Scheffe's (5,2) model to optimize nylon fiber reinforced concrete (NFRC) for compressive strength, achieving 21.96 MPa. Unlike previous empirical approaches, this model-based method offers a more economical and reliable mix design, though further validation on durability and field performance is recommended [21].

This research investigates the effect of the addition of nylon fibers on the workability and mechanical properties of concrete. Two mixes were made: Plain Cement Concrete (PCC) and Nylon Fiber Reinforced Concrete (NFRC), each with nylon fibers incorporated at 3% cement weight. The two mixes were subjected to slump, temperature, and 28-day compressive strength under standard ASTM methods. Uniform mixing, precise curing, and precise measurement of strengths for comparison were ensured through the methodology. The inclusion of 3% nylon fibers imparts toughness and energy absorption, leading to long-term performance and less maintenance in application situations.

2 Research Methodology

2.1 Raw Materials

The fundamental components utilized in this research were Ordinary Portland Cement (OPC), well-graded sand as fine aggregate, crushed granite coarse aggregates with a nominal maximum size of 20 mm, clean potable water, and synthetic nylon fibers with a length of 50 mm. All materials were sourced from local suppliers and were selected based on their conformity with construction-grade quality standards. The nylon fibers were smooth and flexible, making them suitable for enhancing the mechanical properties of concrete without inducing brittleness or compromising mix uniformity.

2.2 Mix Design

To study the influence of nylon fibers on the compressive strength of concrete, two types of concrete mixes were developed: one for Nylon Fiber Reinforced Concrete (NFRC) and the other for conventional Plain Cement Concrete (PCC). The NFRC mix was proportioned by weight using a (cement: sand: aggregate) ratio of 1:4:2, corresponding to 6.5 kg of cement, 26 kg of sand, and 13 kg of coarse aggregate. A water-cement ratio of 0.6 was maintained throughout to provide a balance between workability and strength development. Nylon fibers were added at 3% by weight of cement, a dosage selected based on literature supporting its effectiveness in improving ductility and crack resistance. The conventional PCC mix followed a typical 1:2:4 ratio, commonly used in non-reinforced structural applications, with the same water-cement ratio (0.5) to maintain comparability with the fiber-reinforced variant as shown in Table 1. In fiber-reinforced concrete (FRC), uniform fiber distribution is critical. A higher proportion of fine aggregates (sand) in the 1:4:2 mix helps create a denser matrix and improves fiber bonding. Coarse aggregates in higher proportion (as in 1:2:4) can lead to fiber balling and poor distribution. Concrete mixing was carried out in a mechanical drum mixer. The dry ingredients (cement, sand, and aggregates) were first blended in five successive layers to avoid the fiber "balling effect" and ensure even distribution. Once a uniform dry mix was achieved, water was added gradually and mixing continued for 5 minutes to achieve a homogeneous wet mix. Immediately after mixing, temperature measurements were recorded for the fresh concrete using a standard concrete thermometer. Slump tests were conducted in accordance with ASTM C143 to evaluate the workability and consistency of both the NFRC and PCC mixes. Concrete samples were cast into standard cylindrical molds of 4 inches (100 mm) in diameter and 8 inches (200 mm) in height. The molds were filled in three layers; each layer compacted to eliminate trapped air and ensure uniform density. After 24 hours of ambient curing, the specimens were demolded and placed in a curing tank containing clean water. The samples were cured for 28 days, in compliance with ASTM C192, to allow full hydration and strength development.

Table 1: Table showing the mix design of Nylon fiber Reinforced and Plain Cement Concrete

Description	Mix Ratio	Cement (kg)	Sand (kg)	Aggregates (kg)	W/C Ratio	Fiber Length (50 mm)	Fiber Dosage (%)	Mixing Time (Minutes)
PCC	1:2:4	6.5	13	26	0.5	-	-	05
NFRC	1:4:2	6.5	26	13	0.6	Nylon	3	05

2.3 Testing and Parameter

To thoroughly evaluate the performance characteristics of both Nylon Fiber Reinforced Concrete (NFRC) and Plain Cement Concrete (PCC), a systematic testing protocol was implemented based on standardized procedures. The testing focused on both fresh and hardened concrete properties. Fresh concrete testing involved the measurement of slump and temperature to assess workability and mixing consistency. The slump test was conducted according to ASTM C143 using a standard slump cone to determine the flowability and ease of placement of the concrete mixes. Temperature readings were recorded using a digital concrete thermometer in line with ASTM C1064/C1064M, ensuring consistency in environmental and mixing conditions.

For hardened concrete evaluation, compressive strength testing was carried out in accordance with ASTM C39/C39M. Cylindrical specimens with dimensions of 100 mm in diameter and 200 mm in height were prepared for both NFRC and PCC. The concrete was placed in molds in three successive layers; each layer compacted to remove air voids and achieve uniform density. After casting, the specimens were demolded following a 24-hour setting period and transferred to a curing tank filled with clean water, where they were cured for 28 days as per ASTM C192/C192M to ensure complete hydration and strength development.

Post-curing, the specimens were subjected to compressive strength testing using a Universal Testing Machine (UTM). The machine applied a continuous axial load at a controlled rate until the point of failure. The maximum load sustained by each specimen was recorded and used to calculate compressive strength based on the specimen's cross-sectional area. These tests provided key parameters for comparing the mechanical behaviour and consistency of NFRC and PCC under compressive loads. By adhering strictly to standard procedures, the obtained data were ensured to be reliable and suitable for comparative analysis in evaluating the impact of nylon fiber reinforcement on concrete performance.

3 Results

3.1 Workability behaviour

To evaluate the mechanical performance of both Nylon Fiber Reinforced Concrete (NFRC) and conventional Plain Cement Concrete (PCC), a series of tests were conducted on both fresh and hardened concrete specimens. Immediately after mixing, fresh concrete properties were assessed through temperature and slump tests. These parameters provided valuable insight into the behaviour of fresh NFRC compared to PCC. The slump test, as shown in Figure 1, conducted in accordance with ASTM C143, measured the workability and flowability of the mix. PCC exhibited a slump of 150 mm, indicating moderate workability suitable for general structural applications. In contrast, NFRC showed a higher slump of 190 mm, suggesting better workability, which may be attributed to the higher water-cement ratio and the lubricating effect of nylon fibers enhances workability by reducing internal friction and promoting smoother flow of the concrete mix.

a)  b) 

Figure 1: a. Showing the slump of PCC, and b. Slump of NFRC

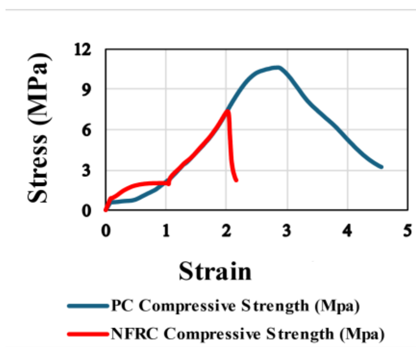
a)  b) 

Figure 2: a. Showing the Temperature of PCC, and b. Temperature of NFRC

The temperature of fresh concrete was measured using a standard concrete thermometer. PCC registered a temperature of 30.6°C, while NFRC measured 30.7°C, as shown in Figure 2, indicating a negligible difference and confirming consistent mixing and ambient conditions during sample preparation.

3.2 Compressive Behaviour

After 28 days of water curing, compressive strength tests were carried out using a Universal Testing Machine (UTM) in accordance with ASTM C39. This test involved applying a gradual compressive load on cylindrical concrete specimens until failure occurred as shown in Figure 3. The load of failure was recorded in kilonewtons (KN) and converted to compressive strength in megapascals (MPa) based on the cross-sectional area of the specimen.



a)

b)

Figure 3: a. Showing graphical results of the compressive strength of NFRC vs PCC, and b. Specimen under UTM

3.3 Compressive and Workability Properties of NFRC and PCC

The PCC specimens showed compressive load values of 60.308 KN, and 86.472 KN, corresponding to compressive strengths of 7.440 MPa, and 10.66 MPa, respectively. The average compressive strength for PCC was calculated to be approximately 9.05 MPa, with a standard deviation of 1.614 MPa and a coefficient of variation (COV) of 17.83%, indicating moderate variability in strength performance. On the other hand, NFRC specimens recorded compressive load values of 59.582 KN, and 55.192 KN, resulting in compressive strengths of 7.351 MPa, and 6.808 MPa, respectively. The average compressive strength of NFRC was 7.07 MPa, with a lower standard deviation of 0.384 MPa and a COV of 5.43%, as shown in Table 2, suggesting greater consistency in test results compared to PCC.

Table 2: Table showing the Compressive strength and workability properties of Nylon fiber Reinforced and Plain Cement Concrete

Description	Slump (mm)	Temperature (C°)	Load (KN)		Compressive Strength (MPa)		SD (MPa)	COV (%)
PCC	150	30.6	60.308	73.39	7.440	9.05	1.614	17.83
			86.472		10.66			
NFRC	190	30.7	59.582	57.39	7.351	7.07	0.384	5.43
			55.192		6.808			

Although the inclusion of 3% nylon fibers contributed to enhanced workability and potentially better post-cracking behavior, the compressive strength of NFRC was found to be lower than that of conventional PCC. This reduction in strength could be attributed to the higher water-cement ratio in the NFRC mix and the potential disruption in the matrix compaction caused by excessive fiber content. However, the ductility and crack-resisting properties of NFRC may offer structural advantages in specific applications where toughness and energy absorption are prioritized over peak compressive strength.

Overall, the results highlight that while NFRC may slightly compromise compressive strength compared to traditional PCC, it offers superior workability and may perform better in applications requiring improved durability and tensile behavior.

4 Practical Implementation

The practical use of Nylon Fiber Reinforced Concrete (NFRC) is highly promising in the field of civil engineering projects, particularly where ductility, crack control, and workability are critical performance parameters. Adding nylon fibers improves the post-cracking performance of concrete, and hence it is a good substitute in applications where small surface cracks have the potential to critically impair durability and lifespan. NFRC is particularly beneficial in non-structural uses like pedestrian pavements, parking lots, sidewalks, and thin overlays where conventional Plain Cement Concrete (PCC) is vulnerable to early-age cracking and shrinkage. The enhanced workability evidenced in NFRC facilitates easier placement and compaction in formworks with complex geometries or dense reinforcement arrangements. This benefit is vital in contemporary construction methodologies that require efficiency but not at the expense of quality. Additionally, its excellent microcracking resistance makes it an ideal choice for thin-section members, plaster work, and precast elements exposed to transportation and handling stress prior to final disposal. Aside from static applications, NFRC has great potential in dynamic or vibration-exposed conditions such as in tunnel linings, highway barriers, or light prefabricated members, where plain concrete may be more prone to cracking. Although NFRC is less suitable for high load carrying members because of its lower compressive strength, NFRC still supports conventional concrete in hybrid structures by enhancing ductility and energy absorption. Additionally, the cost of high-quality synthetic fibers can be significantly higher compared to traditional reinforcement, affecting the economic feasibility of large-scale projects. Moreover, the lack of standardized guidelines for mixing and placing fiber-reinforced concrete creates uncertainty in quality control and performance prediction. Its financial viability is also advantage nylon fibers are not expensive and are locally available, so NFRC is a viable and eco-friendly material for mass applications. Provided proper mix design and dosage regulation are followed, NFRC is an effective means of enhancing long-term performance, especially in projects with durability, resistance to cracking, and simplicity of construction as top considerations.

5 Conclusion

This study explored the effectiveness of nylon fiber-reinforced concrete (NFRC). The key conclusions drawn from this study are summarized below

- Nylon Fiber Reinforced Concrete (NFRC) showed improved workability, where the slump was 190 mm as against 150 mm for Plain Cement Concrete (PCC), reflecting improved flowability and ease of placement.
- The average compressive strength of NFRC (7.07 MPa) was slightly less than that of PCC (9.05 MPa), mainly attributed to the increased water-cement ratio (0.6) and fiber interference.
- NFRC is preferably adaptable for lightly loaded or non-structured applications like pavements, footpaths, flooring, and pre-cast units where crack control along with workability is desired.

Generally, NFRC presents a cost-effective and pragmatic solution in construction situations where intermediate strength with improved performance properties is needed.

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