RECENT TREND IN CIVIL ENGINEERING AND BUILT ENVIRONMENT
e-ISSN: 2773-5303

RTCEBE

Vol. 6 No. 1 (2025) 269-275
https://publisher.uthm.edu.my/periodicals/index.php/rtcebe

Exploratory Study on Concrete Tensile and Compressive Strength with Varying Lengths of Nylon Strings

Muhammad Idlan Haris Mohamed Amin[1], David Yeoh Eng Chuan

[1] *Faculty of Civil Engineering and Built Environment*
Universiti Tun Hussein Onn Malaysia, Batu Pahat, 86400, MALAYSIA

*Corresponding Author: david@uthm.edu.my
DOI: https://doi.org/10.30880/rtcebe.2025.06.01.028

Article Info

Received: 08 January 2024
Accepted: 15 April 2024
Available online: 6 May 2025

Keywords

Nylon string, nylon fiber lengths, tensile strength, compressive strength, admixture

Abstract

The study aims to develop nylon-fiber-reinforced concrete by adding 2% per unit volume of 0.16 mm diameter nylon fibers to concrete. It investigates the impact of varying nylon fiber lengths (0 mm, 25 mm, 50 mm, and 75 mm) on the tensile and compressive strength of the concrete. The tensile and compressive strengths were measured after a 28-day curing period. Results showed that concrete with 25 mm fiber length exhibited the highest tensile strength (1.21 MPa), 1.09 times stronger than ordinary concrete. The compressive strength of the 25 mm nylon concrete was also higher (32.43 MPa) than the control samples. Despite meeting C25 concrete specifications, the study suggests further research on the impact of fiber length and diameter, as well as exploring bending, flexural strength, and other factors for a more comprehensive understanding.

1. Introduction

Concrete, a material made of aggregates which have been mixed with water and cement, is considered one of the most important resources in the development of human civilizations. Its high compressive strength is also a factor in why concrete is still being used in the construction of buildings and other structures. However, while concrete structures possess a high compressive strength, its low tensile strength causes it to crack easily when subjected to tension within the structural elements. To overcome the low tensile strength of concrete, concrete composite materials have been created. These composite material concrete mixtures are typically made from concrete mixed with fibrous materials with higher tensile strength. Concrete reinforced with fibers can increase the tensile strength, its compressive strength, improve the fracture toughness, as well as the impact resistance (Wu, et al. 2020). A study by Mukhopadhyay (2009) states that the production of nylon has increased steadily over the years. It also states that nylon fibers are used in the manufacturing of many types of components, which would add to the ease of access to nylon fibers. The objectives of this study were to determine the tensile and compressive strength of concrete with and without nylon fibers and to analyze the difference in tensile strength of concrete with different nylon fiber lengths. This study addresses the issue of low tensile strength in concrete, leading to cracking and structural deformities under tensile stresses. It aims to counteract this problem by examining the high tensile properties of fiber-reinforced concrete. The research focuses on determining the optimum length of nylon fibers to maximize tensile strength in concrete samples, as well as study the effects of the nylon fibers on the compressive strength of the concrete samples. Additionally, the study explores the use of nylon fibers as a readily available material to enhance the overall strength of concrete.

2. Materials and Methods

This segment covers the discussion of the materials and methods used in this study. All materials and methodologies utilized within the scope of this study were selected based on their availability at Universiti Tun Hussein Onn Malaysia (UTHM).

2.1 Properties of Materials

The materials used in this study were cement, fine and coarse aggregates, water, and nylon fibers.

(i) Cement

For the purposes of this study, Ordinary Portland Cement (OPC) was used to create concrete. Concrete is created when cement is used as a binder of aggregates with the added presence of water. Portland cement is one of the most used cements in the globally and was available at the laboratory making the use of OPC more accessible.

(ii) Fine and coarse aggregates

Fine and coarse aggregates were used for the mixing of concrete in this study. Coarse aggregates generate the characteristic strength found in concrete, while fine aggregates fill up the voids in between the coarse aggregates to decrease the presence of voids within the concrete mixture, ensuring a lower possibility of cracking or other structural failures when the concrete is subjected to stresses and strains (Mahmud, 2016). Both were sieved to remove contaminants that may affect the concrete mixing.

(iii) Water

The water that was used to mix the concrete was tap water. As said by Hover (2011), water is a requirement in concrete due to its ability to facilitate the chemical reactions required for the generation of strength and durability within the concrete mixture. However, failure to monitor the water to cement ratio would decrease accuracy and prevent the concrete from achieving the target grade.

(iv) Nylon fibers

The tensile strength of a material is often referred to the amount of stretching and pulling forces it can endure before breaking or failing. As mentioned by Sanders (2019), nylon is often regarded as a fiber with a high amount of tensile strength. The addition of nylon fibers within concrete can be classified as fiber-reinforced concrete (FRC). Based on the studies and tests conducted by the past researchers, it can be said that by adding nylon fibers within concrete mixtures, the overall mechanical properties of the concrete sample will increase as well.

2.2 Methods

Two tests were conducted during this study, a compressive strength test and a tensile strength test. Four sets of samples were created for each test, with one set serving as the control sample set. The other three sample sets had different lengths of nylon fiber, which were 25 mm, 50 mm, and 75 mm. The diameter and unit volume percentage were kept constant between samples, which were 0.16 mm and 2% respectively. For the compressive strength tests, 100 mm x 100 mm x 100 mm cubes were created and 200 mm height and 100 mm diameter cylinders were created for the tensile strength tests. These tests were performed according to the guidelines set by British Standard BS EN 12390-1. Table 1 and Table 2 shows the design mix for the samples.

Table 1 *Concrete samples for the compression test*

Number of samples	Volume of samples (m^3)	Concrete grade	Curing duration (day)	Cement content (kg)	Water content (kg or L)	Fine aggregate (kg)	Coarse aggregate (kg)
18	0.02	C25	28	7.96	3.80	15.30	22.94

Table 2 *Concrete samples for the split-tensile test*

Number of samples	Volume of samples (m^3)	Concrete grade	Curing duration (day)	Cement content (kg)	Water content (kg or L)	Fine aggregate (kg)	Coarse aggregate (kg)
20	0.032	C25	28	12.67	6.08	24.48	36.70

Three tests were performed on both the fresh and hardened concrete samples. The first test which was performed on the fresh concrete samples was the slump test, whereas the compression test and the split-tensile test were performed on the hardened concrete samples. For the slump test, the equipment involved a metallic cone mould with the dimensions of a height of 300 mm, a top diameter of 100 mm, and a bottom diameter of 200 mm. Based on the British Standard BS EN 12350-2, three layers of concrete were filled inside the mould, with each layer being tamped with a tamping rod 25 times between each layer. To achieve the optimal results in a slump test, the resulting slump had to be a true slump after performing the test. After the concrete mix was deemed satisfactory, the samples were then placed in their moulds in layers with each layer being tamped 25 times and left for 24 hours, after which the samples were placed in curing tanks.

(a) **(b)**

Fig. 1 *(a) Slump test conducted on concrete mix sample; (b) Slump value observed from the concrete mix sample*

The compression test performed was based on the British Standard BS EN 12390-3. 18 samples of concrete cubes were tested once the concrete had hardened after curing for 28 days. Three control samples were produced, and five samples were created for each difference in length of nylon fibres which were 25 mm, 50 mm, and 75 mm. Each concrete cube sample had a volume of 0.001 m^3, and with five samples and 10% of wastage accounted for each sample, the total volume of the samples in each category was 0.0055 m^3. The equipment involved in the testing process was a Universal Testing Machine (UTM), where a load was continually applied onto the samples at a rate which is constant until the sample broke or failed. For the split-tensile strength test, the number of cylindrical concrete samples that was used was 20. Five samples were created for the control samples as well as each difference in length of nylon fibres which were 25 mm, 50 mm, and 75 mm. Each concrete cylinder sample had a volume of 0.00157 m^3, and with five samples in each set of categories and 10% of wastage accounted for each sample, the total volume of the samples was 0.00863 m^3. The test performed followed the guidelines stated in the British Standard BS EN 12390-6 to acquire the optimal results. Much like the previous test, the tensile strength test was conducted using the UTM. A diametral compressive load was applied constantly along the length of the cylindrical concrete sample until cracking or failure occurred. The data collected from the tests were tabulated and analysed to obtain the tensile strength of the concrete cylinder samples. Figure 2 shows the samples during the test.

(a) **(b)**

Fig. 2 *(a) Concrete cube sample under compression in UTM; (b) Splitting test performed on sample using the UTM*

3. Results and Discussion

The results of this study were derived from laboratory tests and experimental observations. This section delves into the outcomes of tests examining density, compressive strength, and split-tensile strength.

3.1 Density of Concrete

It was observed that the average densities of the concrete cube samples increased at 25 mm length of nylon fiber, however decreased at 50 mm, and slightly increased again at 75 mm. It was noted that the densities of the concrete cubes increased after curing. For the concrete cylinder samples, the average densities decreased compared to the control samples, however increased at a steady rate with the addition of longer fibers. It was noted that the densities of the samples increased after curing. Figures 3 and Figures 4 shows the densities of the samples.

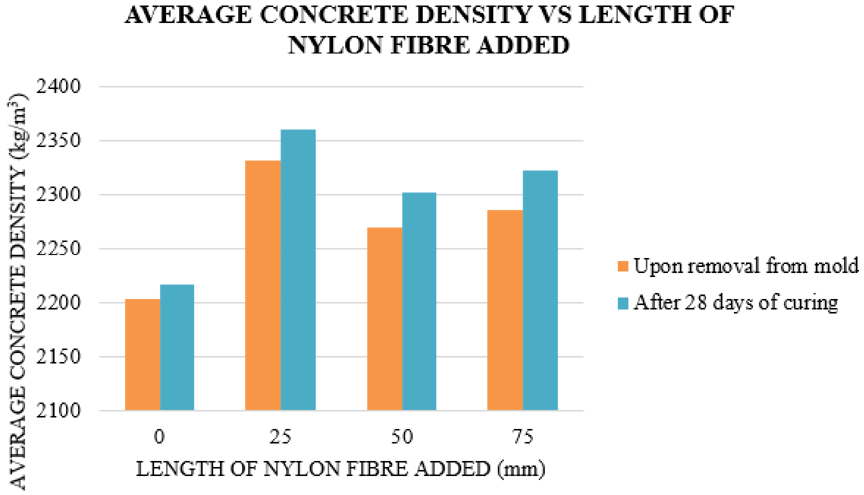

Fig. 3 *Average density of concrete cube samples*

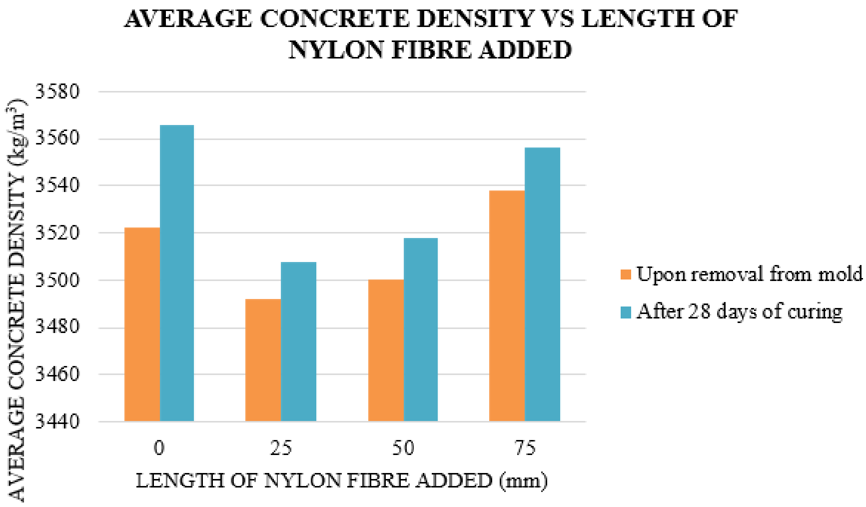

Fig. 3 *Average density of concrete cylinder samples*

3.2 Compressive Strength of Concrete Samples

Based on Figures 4 and 5, as the length of nylon fibers increases in concrete samples, their average compressive strength decreases. The peak compressive strength occurs at a length of 25 mm, followed by a decline at 50 mm and stabilization at 75 mm. Notably, concrete cubes with added nylon fibers exhibit higher average compressive strength compared to control samples. The study's results reveal that, after 28 days of curing, concrete with 2% nylon fibers (0.16 mm diameter, 25 mm length) achieves optimal compressive strength at 32.43 MPa. In contrast, samples with 50 mm and 75 mm nylon fibers show lower average compressive strengths at 30.81 MPa and 30.84 MPa, respectively. The marginal increase at 75 mm is considered negligible. Past research indicated optimal strength at 50 mm length, but due to nylon fiber diameter, the 25 mm length achieved optimal strength.

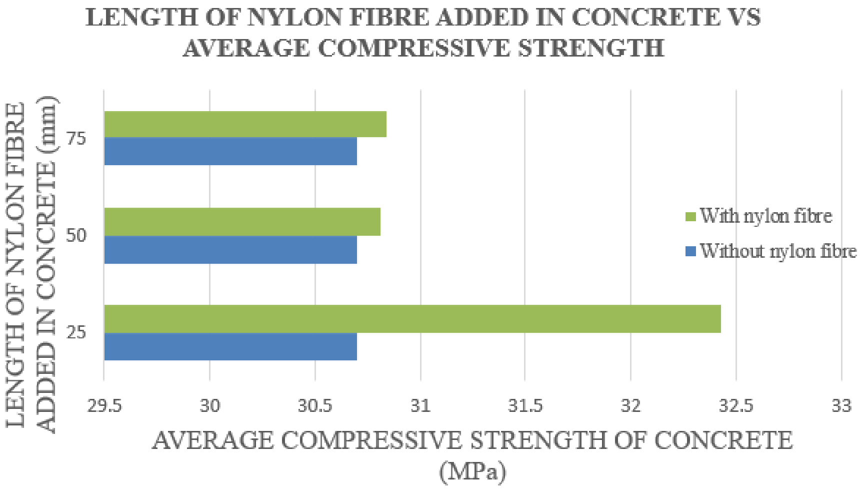

Fig. 4 *Average compressive strength of concrete with and without nylon fibre in concrete*

3.3 Tensile Strength of Concrete Samples

Based on Figures 5 and 6, the average compressive strength in concrete peaks at 25 mm length of nylon fiber, diminishes at 50 mm, and slightly increases at 75 mm. However, in contrast to the compressive strength test results, the tensile strength weakens with increased nylon fiber length, falling below the control sample's tensile strength. Based on the study's findings, the ideal length for added nylon fibers in concrete mixtures is determined to be 25 mm. The addition of 25 mm nylon fibers (0.16 mm diameter, 2%-unit volume concrete) as an additive for concrete yields an ideal tensile strength of 1.21 MPa after 28 days of curing. Other samples exhibit lower tensile strength values, with 50 mm and 75 mm lengths of nylon fibers showing average tensile strengths of 1.05 MPa and 1.09 MPa, respectively. The fluctuations in tensile strength values, with a slight increase at 75 mm, is possibly attributed to the nylon strings compacting in the concrete and marginally enhancing tensile capabilities.

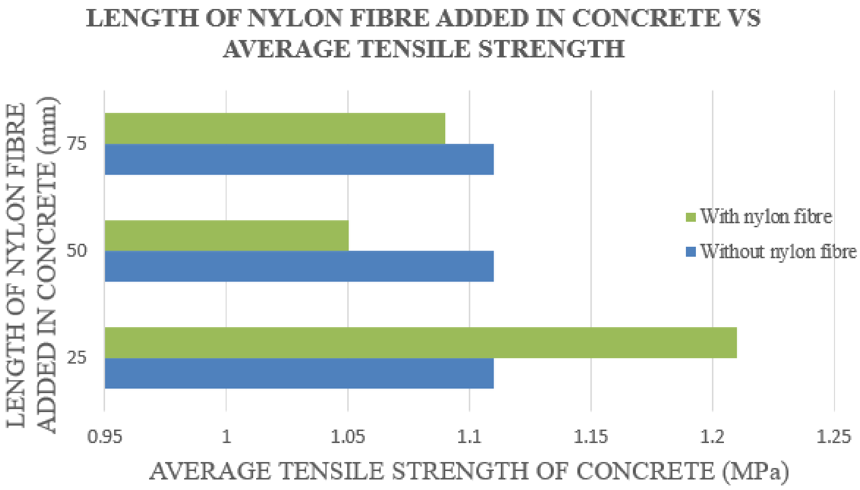

Fig. 5 *Average tensile strength of concrete with and without nylon fibre in concrete*

4. Conclusion

In conclusion, the study successfully explored and achieved its objective in examining the impact of nylon fibers, along with different lengths of nylon fibers, as an additive material in cement on the tensile strength of concrete. The results of the study are described below:

- The density of cylindrical samples increased steadily with the length of nylon fiber, indicating a proportional rise in water absorption. This suggests that longer nylon fibers may retain moisture during curing, enhancing sample density. In terms of tensile strength, samples with 25 mm length nylon fibers demonstrated an increase compared to control samples, while other samples showed lower tensile strength, possibly due to characteristics of nylon fibers disrupting the concrete bond. The study suggests that 25 mm length nylon fibers, comprising 2% of unit volume concrete and with a diameter of 0.16 mm, are optimal for enhancing tensile strength in concrete mixtures. The correlation between increased density and tensile strength may be attributed to longer fibers creating denser samples, but potential issues like fiber bunching or compaction errors could weaken the concrete structure.
- Samples with 25 mm length nylon fibers showed a significant increase in tensile strength from 1.11 MPa to 1.21 MPa compared to control samples. However, as the nylon fiber length increased to 50 mm, the average tensile strength decreased to 1.05 MPa, reaching its lowest value in the study. At 75 mm length, the average tensile strength slightly increased to 1.09 MPa. The pattern indicates that while the addition of nylon fibers enhances tensile strength, lengths beyond 25 mm may weaken it, falling below the average tensile strength of conventional concrete. In terms of compressive strength, the results parallel the tensile strength findings, with the average compressive strength of every concrete sample containing added nylon fibers still surpassing control samples. The 25 mm length nylon fiber samples exhibited the highest compressive strength at 32.43 MPa. Despite the study's focus on tensile strength, the results demonstrate that adding nylon fibers to concrete enhances various factors, including compressive strength, potentially achieving C25 grade standards.

There are recommendations for further research, which are described below:

- Considering the diameter and percentage of the nylon string fiber will influence the tensile strength of the concrete, adjusting them will expand the scope of this exploratory inquiry. Thus, the optimal tensile strength may be compared if the diameter or percentage changes but the length of fiber added stays the same.
- It is conceivable to expand up to 100 mm and 125 mm of nylon fiber as extra nylon fiber length parameters. As a result, the ultimate strength of concrete after the addition of newer nylon fiber lengths may be determined. It will also be helpful to obtain the pattern of the strengthening component of the concrete.
- This study focused exclusively on the concrete's tensile and compressive strengths. Investigating the effects of the percentages on the bending and flexural strength, among other things, is therefore recommended for a more thorough research outcome.
- Extreme care should be taken when performing the manual tests and sample preparation as poor implementation of procedures will result in faulty and defective findings. The objectives and the scope of the study would not be achieved.

Acknowledgement

The authors express their gratitude to the Faculty of Civil Engineering and Built Environment at Universiti Tun Hussein Onn Malaysia (UTHM) for providing testing facilities and ongoing support.

Conflict of Interest

Authors declare that there is no conflict of interests regarding the publication of the paper.

Author Contribution

The authors confirm contribution to the paper as follows: ***study conception and design:*** *Amin and Yeoh;* ***data collection:*** *Amin;* ***analysis and interpretation of results:*** *Amin and Yeoh;* ***draft manuscript preparation:*** *Amin and Yeoh. All authors reviewed the results and approved the final version of the manuscript.*

References

Aïtcin, P.-C. . (2016). Portland cement. *Science and Technology of Concrete Admixtures*, 27–51. https://doi.org/10.1016/b978-0-08-100693-1.00003-5

Alexander, M., Mindness, M. (2005). *Aggregates in Concrete*. CRC Press. https://doi.org/10.1201/9781482264647

British Standards Institution. (2009). *Testing hardened concrete. Part 8, Depth of penetration of water under pressure.* Bsi.

Dewangan, R., Khare, G., & Sahu, M. (2019). INFLUENCE OF VARIATION OF LENGTH AND DOSAGE OF NYLON FIBER ON COMPRESSIVE AND SPLIT TENSILE STRENGTH OF CONCRETE. In *International Research Journal of Engineering and Technology*.

Hover, K. C. (2011). The influence of water on the performance of concrete. *Construction and Building Materials*, *25*(7), 3003–3013. https://doi.org/10.1016/j.conbuildmat.2011.01.010

Mainak, B., Debarshi, N., Soumadeep, M., & Arka, G. D. (2020). An Experimental Investigation of the Behavior of Nylon Fibre Reinforced Concrete. *An Experimental Investigation of the Behaviour of Nylon Fiber Reinforced Concrete*, *7*(9), 133–139.

Manikandan[1], K., Arun, A., Deepak, M., Manikandan, V., & Sathish Kumar, K. (2017). EXPERIMENTAL INVESTIGATION ON NYLON FIBER REINFORCED CONCRETE. In *International Research Journal of Engineering and Technology*. IRJET.

Mir, M., Abhijit, N. A., Maysha , U., & Sharmin , R. C. (2023). REVIEW ON CONVENTIONAL CONCRETE AND NYLON FIBER REINFORCED CONCRETE BEHAVIOR. *Malaysian Journal of Civil Engineering*, *35*(1), 7–15. https://doi.org/10.11113/mjce.v35.19045

Mujahid, H. L., Noor, A. M., & Muneeb, A. M. (2021). Effect of using Nylon Fibers in Self Compacting Concrete (SCC). *Civil Engineering Journal*, *7*(8), 1426–1436. https://doi.org/10.28991/cej-2021-03091734

Mukhopadhyay, S. K. (2009). Manufacturing, properties and tensile failure of nylon fibres. *Handbook of Tensile Properties of Textile and Technical Fibres*, 197–222. https://doi.org/10.1533/9781845696801.2.197

Neville, A. M., & Brooks, J. J. (2010). *Concrete technology*. Prentice Hall.

Resan, S. F., Chassib, S. M., Zemam, S. K., & Madhi, M. J. (2020). New approach of concrete tensile strength test. *Case Studies in Construction Materials*, *12*, e00347. https://doi.org/10.1016/j.cscm.2020.e00347

Sanders, D. (2018, May 10). *What Are High Tensile Strength Plastics? - Reading Plastic M&F*. Precision Plastic Machining, Die Stamping, Custom Plastics & More. https://readingplastic.com/high-tensile-strength-plastics-2/#:~:text=Nylon%20%E2%80%93%20An%20honorable%20mention%20goes

Simpson, P. H. (1989). Cheap, Quick, and Easy: The Early History of Rockfaced Concrete Block Building. *Perspectives in Vernacular Architecture*, *3*, 108. https://doi.org/10.2307/3514298

Ummahat, N., Aziz, A., & Mutsuddy, R. (2021). *Effect of Nylon Fiber Aspect Ratio on the Mechanical Properties of Fiber Reinforced Concrete Effect of Nylon Fiber Aspect Ratio on the Mechanical Properties of Fiber Reinforced Concrete*.

Vu, C.-C., Plé, O., Weiss, J., & Amitrano, D. (2020). Revisiting the concept of characteristic compressive strength of concrete. *Construction and Building Materials*, *263*, 120126. https://doi.org/10.1016/j.conbuildmat.2020.120126

Wight, J. K., & MacGregor, J. G. (2016). *Reinforced Concrete: Mechanics and Design, Global Edition*. Pearson Higher Ed.

Wu, H., Lin, X., & Zhou, A. (2020). A review of mechanical properties of fibre reinforced concrete at elevated temperatures. *Cement and Concrete Research*, *135*, 106117. https://doi.org/10.1016/j.cemconres.2020.106117