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Exploratory Study on Bending Strength of Concrete with Nylon String Fibre

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Abstract

Nylon fiber reinforced concrete has taken on a new role in building industry. Among all other elements involved for transmitting stress between matrix and fibers, aspect ratio has asignificant impact on the mechanical characteristics of the concrete composite. This Abstract is compulsory. The study explores the use of natural nylon string fiber in concrete to enhance its performance, comparing its compressive and bending strength with standard concrete (grade 25) and concrete with nylon fiber at 1%, 2%, and 3% volume. After that, a total of 38 specimens (prisms and cubes) were left cure for a total 28 days in order to ascertain the concrete's mean strength. As a result, the compressive strength enchanced 30.81 MPa with 2% of nylon fiber, the same as bending strength improved by 4.14 MPa after 28 days curing. Aside from that, the aim of this study is to produce nylon-fiber-reinforced concrete by adding 50 mm long and 0.16 mm diameter nylon fibers into concrete. In addition, increasing the percentage of nylon fibre in concrete could reduced its density.

1. Introduction

Concrete is a composite and vital material that has been used in construction for hundreds of thousands of years. It is an important component in the construction of structures and buildings. Because concrete is strong in compression as the aggregate can withstand the compression load and has built-in resistance to fire, it is weakened in tension and brittle. Furthermore, since concrete has a low tensile strength, multiple innovative technologies, and modern standards techniques are being developed, such as using new or recycled materials as substitutes for aggregate or cement in the concrete. The number of raw materials in the concrete mixture rises as a result of the high demand for concrete. Numerous researchers have developed their own techniques to ensure that the strength and durability of the concrete mixture are increased. Alternative materials are typically environmentally friendly cementitious construction materials with good durability and adaptability in developing structures for sustainable construction development.

Over the past few years, there has been growing concern about the use of fibres instead of conventional reinforcement in strengthening or repairing concrete buildings (Ahmad J., 2021). The rehabilitation of reinforced concrete often incorporates both natural and artificial fibres (Yi Wan, 2016). A type of concrete known as fibre-reinforced concrete (FRC) is made with fine and coarse aggregates, hydraulic cement, and fibres. Several fibres have been used for concrete reinforcement, some of which are industrial or waste materials. These fibres include glass fibre, carbon fibre, nylon fibre, polyethylene terephthalate fibre, and polypropylene fibre.

In this study, the nylon fibre (non-metallic fibres) will be put in normal weight of concrete, Nylon is the most extensively utilized due to its affordability, hydrophilic properties, and ease of availability. It is also known for its strength, resilience, and durability. The quality of concrete increases when nylon fibres are added. When compared to traditional cement concrete, nylon fibre reinforced concrete exhibits superior permeability, frost resistance, impact resistance, tensile strength, and flexural strength (Ozawa K., 1989). Nylon fibre is a great way to improve the strength qualities of concrete used in building projects. The main issue with reinforced cement concrete structures is steel reinforcement corrosion, which might compromise the long-term viability and resilience of the current RC structures. By utilizing nylon fibre reinforced concrete, the impact of corrosion may be decreased. An increase in nylon content in concrete has been discovered to improve its mechanical qualities (Martínez-Barrera, 2005). In order to improve the performance of concrete, a small amount of longer nylon fibre can also be utilized (Spadea, Farina, Carrafiello, & Fraternali, 2015). It has also been shown that adding nylon fibre increases the durability of concrete. Lastly, the overall cost of building may be decreased by substituting fibres for the traditional and labour-intensive methods of using steel bars and wire mesh (Wang Y., Wu HC, Li VC, 2000). Construction costs, labour costs, maintenance costs, and project completion time will all go down as a consequence (Yin S., Tuladhar, Shi F, et al., 2015). Since less fibre is normally utilized than the amount of raw materials needed to create traditional reinforcement, power will also be conserved.

2. Materials Properties

2.1 Cement

In this investigation, ordinary Portland cement (OPC), It was produced in accordance with the Malaysian Standard, BS EN 12390-1:2009. Table 1 depicts the oxide composition of cement.

Table 1 *Approximate composition limits of Portland Cement (Neville, 2006)*

Oxide	Content, %
Calcium oxide, Ca O	60 – 67
Silica, SiO_2	17 – 25
Alumina, $A1_2O_3$	3 – 8
Iron oxide, Fe_2O_3	0.5 – 6.0
Magnesium oxide, MgO	0.1 – 4.0
Alkalis	0.2 – 1.3
Sulphur trioxide, SO_3	5

2.2 Coarse aggregate

According to BS EN 1260, the maximum size of coarse aggregates that can be utilized is 20 mm or larger than the maximum size of fine aggregates, which is 4 mm.

2.3 Fine aggregate

Sand is a common fine aggregate used in concrete. Before mixing, the sand needs to be totally dry to avoid any excess water that might change the water content of the concrete. This experiment will use fine aggregates, which are particles smaller than 4 mm, in accordance with BS EN 1260.

2.4 Nylon fiber

Nylon is hydrophilic, sterile, heat stable, chemically inert, and resistant to a wide range of materials. Nylon is an excellent material for giving concrete flexural hardness and impact resistance, as well as preserving and improving load-bearing capacity after the first cracks. In this study, nylon-fiber-reinforced concrete was adding by 50 mm long and 0.16 mm diameter nylon fibers into concrete. Table 2 show the properties of nylon fiber.

Table 2 *The properties of nylon fiber (Manikandan, 2017)*

Material	100% virgin fiber
Tensile strength	896 – 965 MPa
Young's Modulus	5175 MPa
Melt point	225 ℃
Chemical resistance	Good
Alkali resistance	Excellent

Acids and salts resistance	Good
Electrical conductivity	Low
Thermal conductivity	Low
Ultra-violent resistance	Excellent
Specific gravity	1160 kg/m^3
Form	Monofilament

Fig. 1 *Nylon string fiber*

2.5 Water

Water serves as a lubricant when combined with other composite materials, such as concrete, to create a binding paste. With the aid of water, the concrete mixture is readily poured into the mold. There shouldn't be any acidity, alkalinity, or impurities like oil in water. Lab tap water, which has to be more alkaline than 6, will be added to the combination.

3. Methodology

The BS EN 1260 and BS EN 12390 standards are used for all material selection, specimen size, concrete mix design (M25), casting, curing, compressive and bending strength tests. The dimensions of the prism specimen are 100 mm x 100 mm x 400 mm, while the cube specimen is 100 mm x 100 mm x 100 mm.

3.1 Preparation of concrete mixing

The study requires a total of 38 specimens, including 18 cubes and 20 prism samples. The figure below depicts the mixing of C25 concrete cubes with prism specimens.

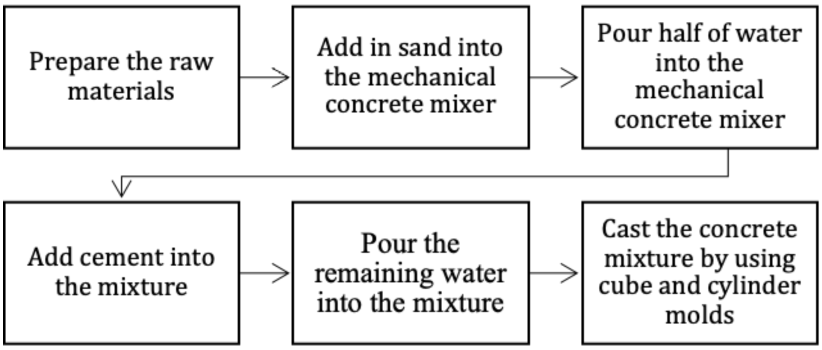

Fig. 2 *Flowchart of C25 concrete mixture preparation*

3.2 Curing of concrete

Concrete will be cast, and the mold will be taken out after a full day. Portable water will then be used to cure the concrete. For 28 days, the specimen is totally immersed in transportable water. It will be tested after the curing process is complete.

3.3 Testing of hardened concrete

3.3.1 Compressive strength test

Table 3 *Number of C25 concrete samples will be prepared for compression test*

Sample notation	Fiber addition (%)	Number of specimens	Remark
C0	0	3	Control sample
C1	1	5	1% nylon fiber
C2	2	5	2% nylon fiber
C3	3	5	3% nylon fiber

Table 4 *Mix proportion of 18 cube samples at 28th day of curing process*

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	0.035	C25	28	12.63	7.32	29.5	44.16

Fig. 3 *Compression test in accordance with BS EN 12390: Part 3*

Table 3 displays the samples that will be prepared for compression testing using the universal testing machine seen in Figure 3. Meanwhile, Table 4 displays the mix proportions of 18 cube samples on the 28th day of curing process.

3.3.2 Flexural strength test

Table 5 *Number of C25 concrete samples will be prepared for flexural test*

Sample notation	Fiber addition (%)	Number of specimens	Remark
F0	0	5	Control sample
F1	1	5	1% nylon fiber
F2	2	5	2% nylon fiber
F3	3	5	3% nylon fiber

Table 6 *Mix proportion of 20 prism samples at 28th day of curing process*

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	0.10	C25	28	36.08	20.90	84.5	126.17

Fig. 4 Bending *test in accordance with BS EN 12390: Part 5*

Table 5 lists the samples that will be produced for the flexural test using the machine shown in Figure 4. Meanwhile, Table 6 depicts the mix proportion of 20 prism samples on the 28th day of curing procedure. The specimen's condition following the bending test is displayed in Table 7.

Table 7 *20 prism samples contain 1%, 2% and 3% after bending test*

	
Control	1%
	
2%	3%

4. Result and Discussion

Table 8 *Compressive and bending strength of 28 days*

Specimen type	Average mean compressive strength (MPa)	Average mean bending strength (MPa)
Control	30.70	3.60
1%	18.31	3.84
2%	30.81	4.14
3%	25.75	3.99

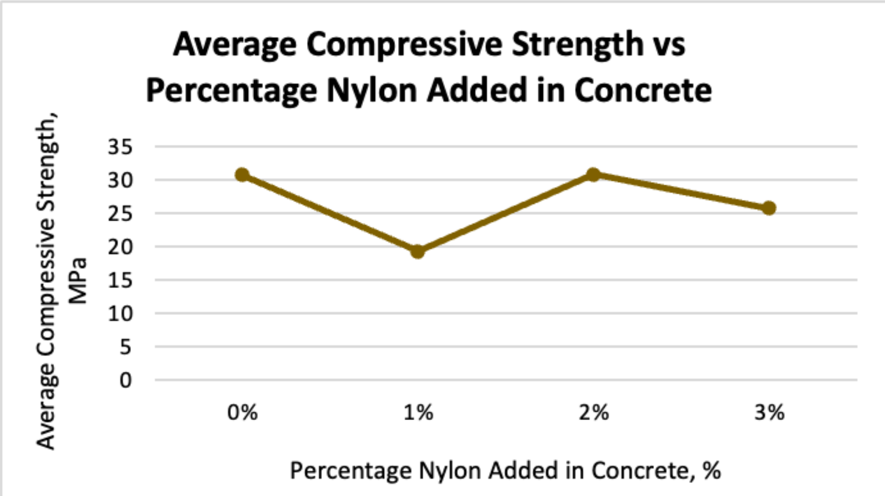

Fig. 5 *Relationship between variations in the nylon string fiber addition percentages of 0, 1, 2, and 3% with the average compressive strength of the concrete samples*

Table 8 and Figure 5 illustrate the compressive strength of concrete made with various fiber kinds. According to one research, after 28 days of curing, the concrete should have achieved 100% of its goal strength, which is 25 MPa. The control specimen achieved an average strength of 30.70 MPa, meeting the minimum required strength of a normal concrete at 28 days, as per the DOE method. The only variations of concrete with 2% and 3% nylon fiber met the minimum strength of 30.81 MPa and 25.75 MPa, respectively. Subsequently, the 1% nylon fiber had a drop of 18.31 MPa, which is more than that of the control specimen. The strength of concrete may decrease due to gaps during fresh concrete preparation, causing voids and wakening (Manjunatha M., Kygd B., 2021).

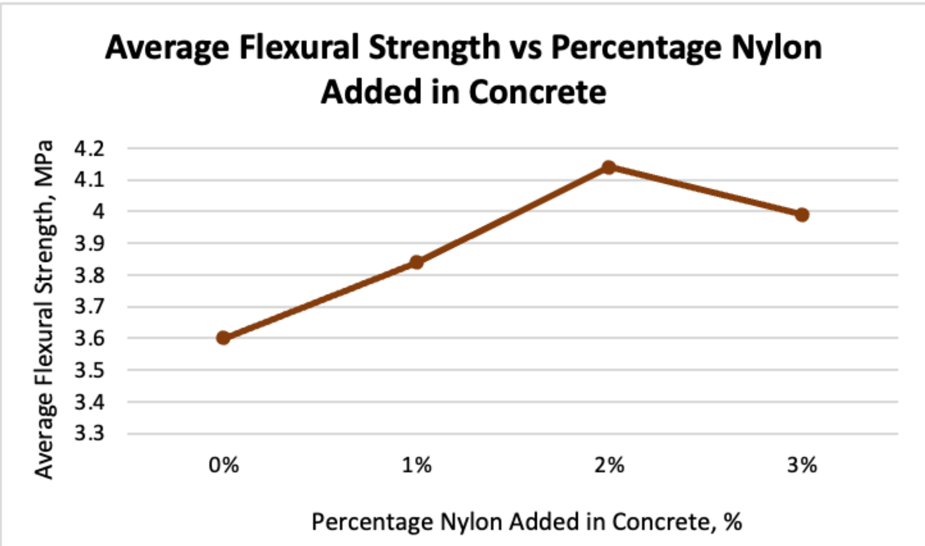

Fig. 7 *Relationship between variations in the nylon string fiber addition percentages of 0, 1, 2, and 3% with the average flexural strength of the concrete samples*

Figure 7 depicts the bending strength of concrete built with different fiber types. The maximum bending strength of 4.14 MPa was achieved with 2% nylon fiber after 28 days of cure. However, when the amount of nylon fiber in concrete is between 1% and 3%, the bending strength decreases from 3.84 MPa to 3.99 MPa. The drop-in strength might be attributed to a change in fiber content; the 2% and 3% changes in fiber content are likely to be greater or less than the 1% variance. Visual observation during concrete mixing found that at 3% nylon string, the fibers became spherical, making it difficult to separate them. Consequently, the balling of fibers had a detrimental effect on strength in any form. This is the main cause of the high proportion of nylon string; the fibers mixed together to form an amalgamation that gives the appearance of holes in the concrete and reduces its bending strength (Bheel. N., 2020).

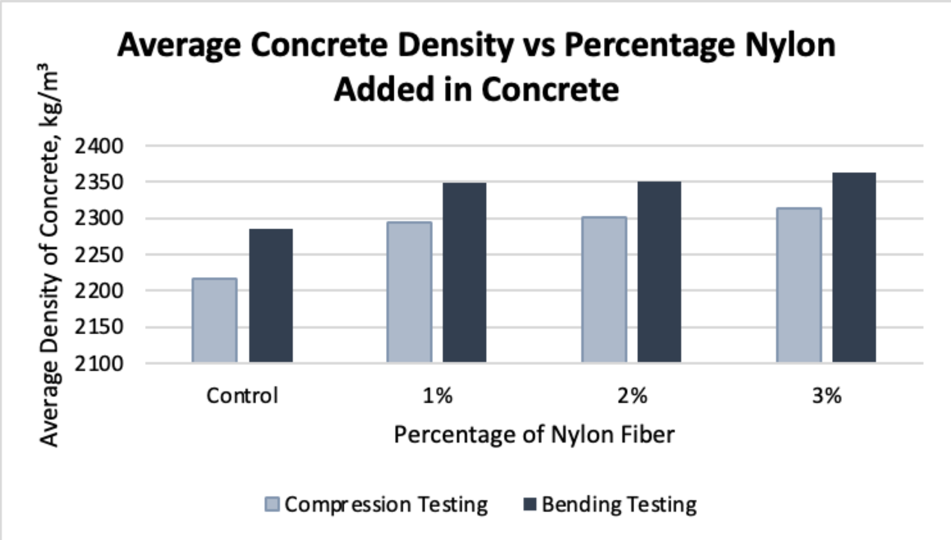

Fig. 8 *Average density for specimen*

Figure 8 shows that the control sample has the maximum density, 2362 kg/m^3, while the lowest density, 2217 kg/m^3, is control specimen lower than the nylon fiber condition. As the amount of nylon fiber in the concrete increased the density value for this study showed an increase in density. Nonetheless, according to BS EN 1992-1-1:2004, the density derived from all of the or this specimen can be accepted. As previously indicated, the average density of cube specimens (compressive test) is lower than that of prism specimens (flexure test), despite the fact that the mixing operation for both types was performed together.

5. Conclusion

Numerous research projects have been conducted to improve the strength, durability, and performance of concrete. Improvements include incorporating fibers like nylon, polypropylene, glass, and steel into the concrete mix. The purpose of this study was to compare the performance of concrete with and without nylon fibers. The study reveals that adding fibers to concrete results in instability in its compressive strength, indicating that the addition of fibers does not enhance its strength. The flexural strength of fiber reinforced concrete is greater than that of conventional concrete. This outcome is due to the interlocking bending strength of fibers in the fiber-bridging zone and failure until the maximum fiber bending strength is achieved. In overall, the best mix designation ratio with the greatest significant result in bending strength is 2% nylon fiber reinforced concrete.

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Conflict of Interest

The 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:*** *Samsuri and Yeoh;* ***data collection:*** *Samsuri;* ***analysis and interpretation of results:*** *Samsuri and Yeoh;* ***draft manuscript preparation:*** *Samsuri and Yeoh. All authors reviewed the results and approved the final version of the manuscript.*

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