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The Effect of Nylon Fibers in Self-Consolidating Concrete (SCC)

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ABSTRACT

Self-compacted concrete (SCC) is a unique type of concrete that settles into the formwork and fills all of its corners without the use of compaction or vibration. Because SCC has a higher flow-ability, it becomes brittle and performs poorly under stress and bending. One of the most effective ways to increase the tensile and flexural performance of SCC is to include randomly distributed short and discontinuous fibres. In this regard this experimental study is undertaken to investigate the effect of nylon fibers (NF) on fresh and hardened properties of SCC. Two different lengths, 20 mm and 12 mm, were used, as well as five different volumetric percentages of NF, 0.1, 0.2, 0.3, 0.4, and 0.5 percent. The results demonstrated that adding NF to SCC had a minor effect on its fresh characteristics. However, the magnitude of the influence is not large enough to be considered a significant factor. According to EFNARC criteria, the fresh characteristics of whole mixtures are within the required range. With the addition of NF, the strength qualities improve. the extent of increment is greater for the longer length of NF. The optimum volumetric fraction of NF for producing high strength SCC was found as 0.5%.The fresh properties of complete combinations are within the required range, according to EFNARC guidelines. The strength properties enhance with the addition of NF. The length of NF has a significant impact on the amount of increment. The volumetric proportion of NF required to produce high-strength SCC was discovered to be 0.5 percent.

***Keywords**: Self-Compacting Concrete; SCC; Nylon Fibers; NF*

1. INTRODUCTION

Concrete is the most commonly utilised man-made construction material on the planet. Concrete has proven to be a global construction material due to its exceptional durability and tremendous compressive strength. Inconvenience is encountered when poring fresh concrete in slabs, beams, beam-column joints, deep and narrow sections, implying that congested areas with significant reinforcing require sufficient compaction. Concrete buildings' durability and strength are affected by improper compaction and vibration. Self-compacting concrete (SCC) may be a preferable option to prevent such difficulties of strength and durability [1]. Self-compacting concrete is a type of concrete that flows under its own weight and fills all corners of formwork without the need for compaction or vibration [2]. Due to its excellent flow ability and great durability, SCC has been widely employed all over the world [3-6]. SCC has a number of advantages over conventionally vibrated concrete, including higher construction quality with dazzling finishing, reduced construction time due to speedier construction, and lower overall construction costs [7]. Although SCC has good flow properties, its brittle nature limits its performance when under tension. Fibers have been shown to increase the performance of concrete, notably in tension and compression.

[8] bending Crack resistance, impermeable surfaces, and improved flexural and fracture toughness of concrete at hardened state are only a few of the benefits of SCC with fibre reinforcing. However, adding fibres to SCC reduces its workability, but the degree of reduction depends on the type, size, and form of the fibres utilised. A balanced fibre distribution, on the other hand, is required to reap the full benefits of fibres [9]. Steel, polypropylene, glass, and other types of fibres have been utilised to evaluate the fresh, hardened, and durability features of SCC. Several studies have recently been conducted to investigate the potential to incorporate various types of fibres into SCC [10-13]. To demonstrate the flow behaviour of fibre reinforced SCC, El-Dieb and Taha [9] employed steel and polypropylene fibres in SCC. Three mixtures were created, each with a different binder content and w/b ratio. The flow properties of steel and polypropylene fibres of various lengths, aspects ratios, and volumetric fractions were evaluated (slump flow, V-funnel and filling box). It was discovered that utilizing fibre reinforcement in SCC can produce acceptable flow characteristics. The mix composition, fibre types, and dosage, on the other hand, have a substantial impact on FRSCC flow performance. Frazao et al. [14] showed the durability qualities of fibre reinforced SCC in their study. Steel fibres with hooks (L= 3mm, dia= 0.5mm, aspect ratio L/d =70) were utilised to create the prototype (FR-SCC). To assess the corrosion resistance, fresh,

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mechanical, and other durability criteria of FRSCC, one controlled SCC mix and other FRSCC mixes with the same w/b ratio of 0.31 were constructed. The results showed that adding steel fibres to SCC was very beneficial in terms of enhancing post-cracking flexural resistance and energy absorption, but had little effect on the fresh and durability parameters of SCC.

Yehia et al. [15] investigated the mechanical and durability parameters of FRSCC using steel and synthetic fibres separately as well as in combination. Synthetic and steel fibres with specific gravity of 0.92 and 7.77 and volumetric fractions of 0.025-0.05 percent and 0.5 percent, respectively, were used. The tests in this study were done in two stages. Workability and strength parameters were investigated in phase one, and FRSCC were treated to wet/dry cycles in phase two. The cube compressive strength of all FRSCC mixtures was found to be greater than 70 MPa. Furthermore, FRSCC was found to increase the mechanical characteristics of all mixes when exposed to early wet/dry cycles. The Nylon is a synthetic polymer-based material with silky surface. Nylon is a strong material that is resistant to abrasion and tearing [16, 17]. The nylon net is mostly used to catch fish. In addition, a large amount of trash nylon net is dumped in the water, polluting the marine ecosystem. These wastes can be used as fibre reinforcement as an ingredient in the manufacturing of concrete to alleviate the environmental issue. The influence of nylon fibres and zeolite ash on the fresh and hardened characteristics of SCC was examined by Afriandini et al. [18]. They employed a volumetric fraction of NF of 1% with a length of 50 mm, and a percentage of ash of 5, 10, and 15% as a partial replacement for cement. The results showed that adding both nylon fibres and zeolite ash significantly improved the strength qualities. It's also possible to conclude that a mixture of 1% NF and 5% zeolite ash produces the best outcomes.

In the manufacturing of SCC, Hanoora et al. [19] employed pineapple leaf fibres and polypropylene fibres. The fibres were 12 mm in length and contained 0.2, 0.3, and 0.4 percent cement by weight. The fresh characteristics were somewhat reduced as the fibre level was increased, according to the findings. As a result, the strength qualities improved. At the age of 28 days, the maximum compressive strength of pineapple leaf fibre and polypropylene fibre was 56.28 MPa and 58.04 MPa, respectively, at 0.3 percent fibre content. Furthermore, at 0.4 percent of both fibres content, the greatest flexural strength was observed. Zoe et al. [20] did research on SCC using metakaolin and nylon fibre. The combined strength properties of nylon fibres and metakaolin in SCC are said to be superior to individual strength properties in concrete. In a cement-based mortar, Habib et al. [21] employed nylon fibre. They reported that the nylon fibers increases the compressive strength of mortarWhen 2% NF was added to a conventional cement-based mortar, the greatest increase of 42.8 percent was found. It was also observed that the length of fibers significantly affects the compressive strength of mortar. The fibers with shorter length cases the decreases in compressive strength. The performance of mortar was improved with addition of higher percentage of longer length of NF [22].

According to the aforementioned review of the literature, there have been very few studies in the domain of SCC with fibre reinforcement, particularly for nylon fibres. The breadth of these investigations, on the other hand, is very narrow, with a wide range of results. To arrive at logical conclusions, a comprehensive and broad-based inquiry is required. As a result, the purpose of this experiment is to see how nylon fibres affect the fresh and hardened qualities of SCC.

2. RESEARCH METHODOLOGY

Figure 1 shows the article's systematic structure, which depicts the order in which different components of the research activity were completed in order to meet the study's objectives.

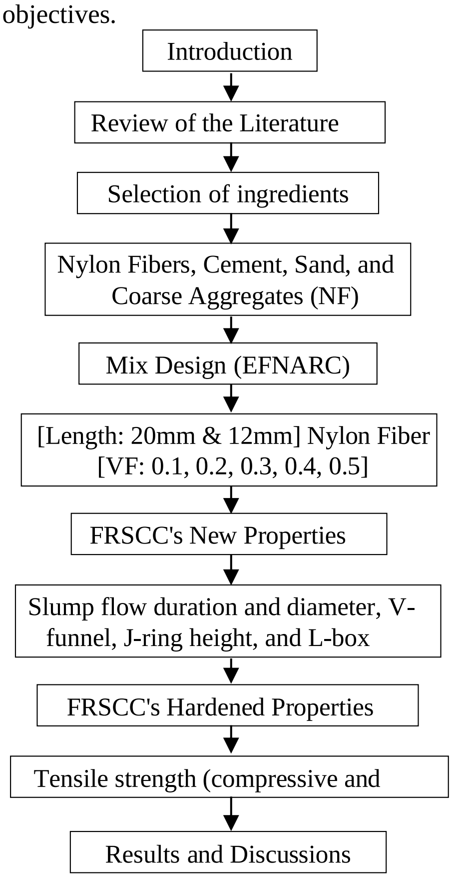

Figure 1: Methodology flowchart and task plan

A total of 11 mixes were created in this study with a fixed w/b ratio of 0.34 and a binder content of 550 kg/m3 [8]. One plain SCC mix and 10 FRSCC mixes with varied lengths (12 and 20mm) and volumetric percentages (0.1, 0.2, 0.3, 0.4, and 0.5 percent) of Nylon fibres were created according to EFNARC criteria [5]. The specifications of the mixes and quantities of materials for one cubic metre of concrete are shown in Table 1.

Table 1. Composition of SCC and FRSCC mixes for 1 m^3

Mixes	Cement Kg/m^3	FA Kg/m^3	CA Kg/m^3	W/B (%)	Water Kg/m^3	Nylon Fibers (%) by volume	SP (%)	SP Kg/m^3
SCC	550	870	890	0.34	187	--	2	11
FRSCC	550	870	890	0.34	187	0.1, 0.2, 0.3, 0.4, 0.5	2	11

2.1. The Materials and Their Origins
2.2. Cement
Ordinary The LUCKY brand of Portland Cement (OPC) complies with ASTM C150M-18 [23]. The cement gradation curve is depicted in Figure 2.

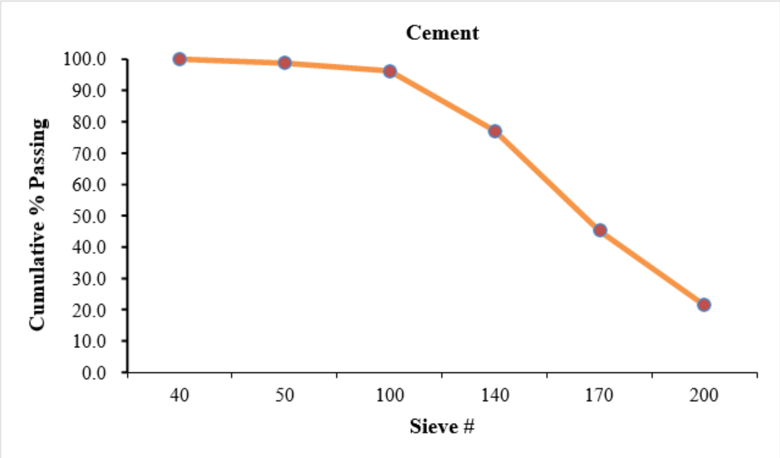

Figure 2: Cement gradation curve

2.3. Fine Aggregates (FA)
Locally available hill sand passing from # 4 sieve as per the specifications according ASTM C 778-02 [24]. The gradation curve for fine aggregates is given in Figure 3.

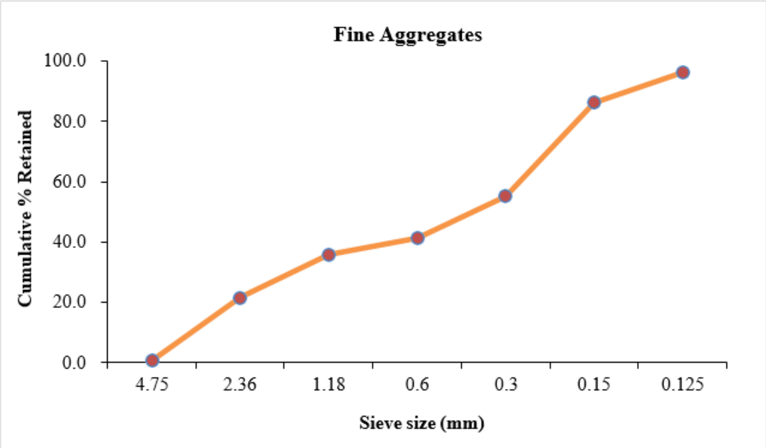

Figure 3: Fine aggregates gradation curve

2.4. Coarse Aggregates (CA)
Natural coarse aggregates with a maximum size of 12.5 mm and gradations as depicted in figure 4 were employed. according to EFNARC standard (EN:12620). The aggregates are washed before using in concrete as per SSD.

Superplasticizer is a term that refers to a (SP)

Throughout the study, a polycarboxylic ether based liquid superplasticizer with the brand name "Master Poly heed 996" was utilised. Water utilised in the fabrication and curing of concrete sample was potable drinking water free of organic and inorganic contaminants.

Nylon Fibers are a type of synthetic fibre (NF)

For the construction of nylon fibre reinforced self-compacting concrete, two different lengths of nylon fibres (20 and 12 mm) and percentage volumetric fractions of 0.1, 0.2, 0.3, 0.4, and 0.5 percent were employed (NFRSCC). The graphical perspective and physical parameters of the nylon fibres employed are shown in Figure 5 and Table 2.

Figure 5: Illustration of Nylon Fibers

Nylon fibres' physical properties are listed in Table 2.

Physical properties	Description
Colour	Transparent white
Fiber length (mm)	20 & 12
Fiber diameter (mm)	0.75
Specific gravity	0.9

3. DISCUSSIONS AND FINDINGS

3.1 Properties that are new

Two key tests were used to evaluate the fresh qualities of SCC and NFRSCC: flow ability and passage ability. Slump flow time T50cm, slump flow diameter, and V-funnel tests were used to measure flow capabilities. J-ring and L-box tests were used to determine passing abilities. Figure 6 depicts a visual representation of a few concrete fresh characteristics testing.

For each mix several trials were carried for optimizing the suitable dosage of superplasticizer to obtain the required values of slump flow time (T_{50cm}) according to the EFNARC guidelines [9]. Table. 1 shows the optimized value of SP for both the controlled mix and FRSCC mixes.

Table 3. Fresh properties of SCC and FRSCC

S. No.	Mixes	Slump flow time T50 (sec) limits 2-5 sec		Slump flow diameter (cm) limits 65-80 cm		V-funnel time (sec) limits 8-25 sec		J-ring height (mm) limits 0-10 mm		L-box height ratio limits 0.8-1.0	
		NF Length (20mm)	NF Length (12mm)	NF Length (20mm)	NF Length (12mm)	NF Length (20mm)	NF Length (12mm)	NF Length (20mm)	NF Length (12mm)	NF Length (20mm)	NF Length (12mm)
1	SCC	2.2		76		8.2		7.8		0.94	
2	0.1% FRSCC	3	2.8	74.12	75.5	11	10.6	8.1	8.2	0.9	0.91
3	0.2% FRSCC	3.4	3.1	73.55	74.3	12.5	11.7	8.34	8.45	0.87	0.89
4	0.3% FRSCC	4.2	3.8	72.04	73.11	13.6	12.3	9.2	8.98	0.84	0.85
5	0.4% FRSCC	4.9	4.4	71.39	72.5	15.6	13.9	9.48	9.3	0.82	0.83
6	0.5% FRSCC	5.1	4.8	70.35	71.17	16.3	15.6	9.8	9.61	0.8	0.81

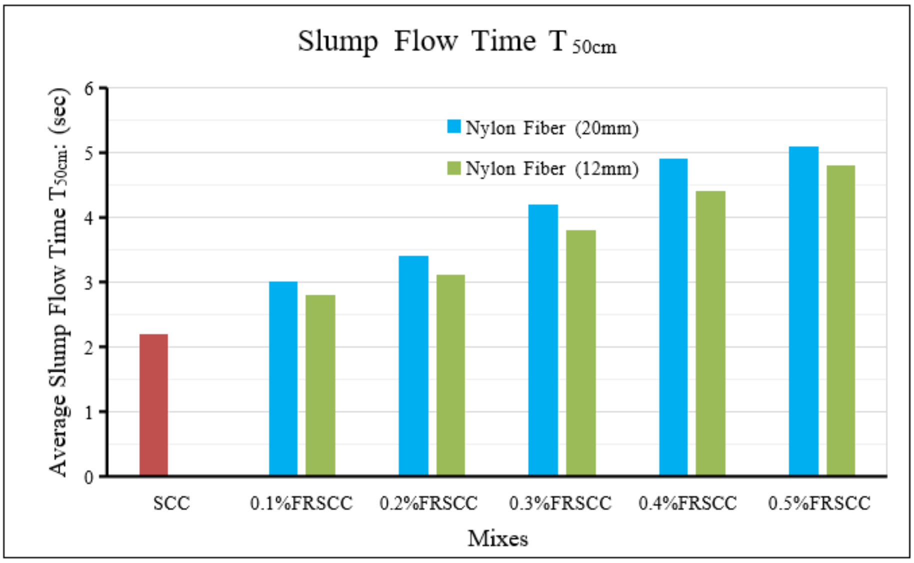

Figure 7. Effect of Nylon fiber on Slump Flow Time of FRSCC

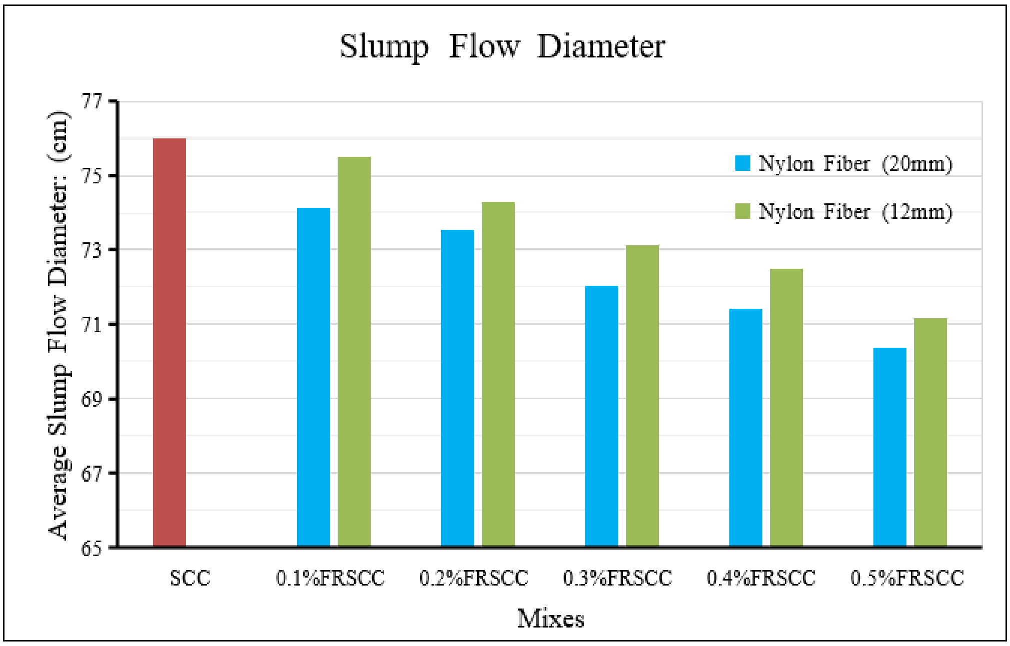

Figure 8. Effect of Nylon fiber on Slump Flow Diameter of SCC and FRSCC

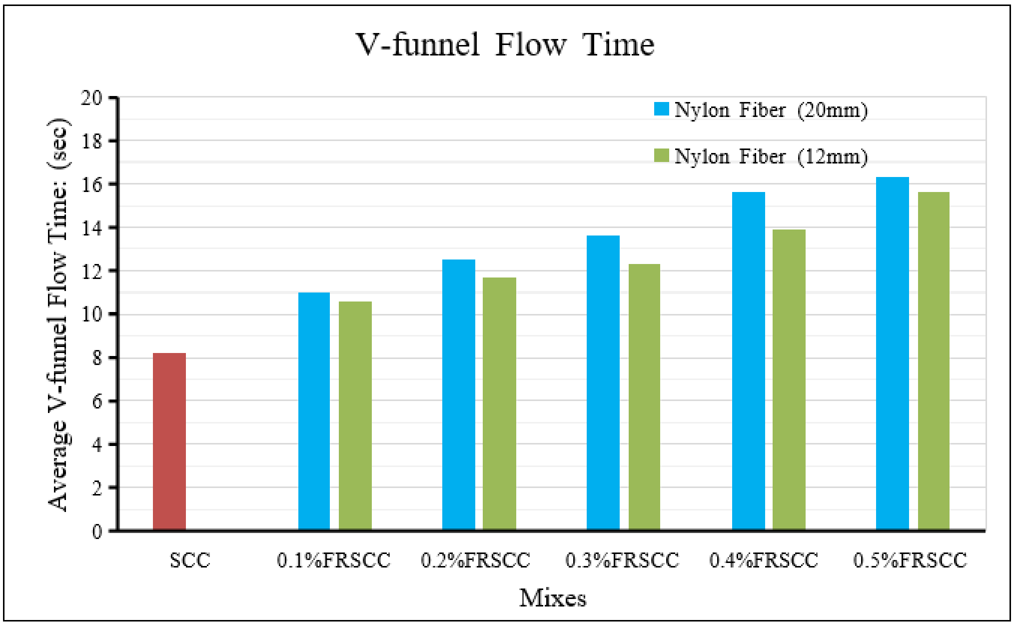

Figure 9. Effect of Nylon fiber on V-funnel flow time of FRSCC

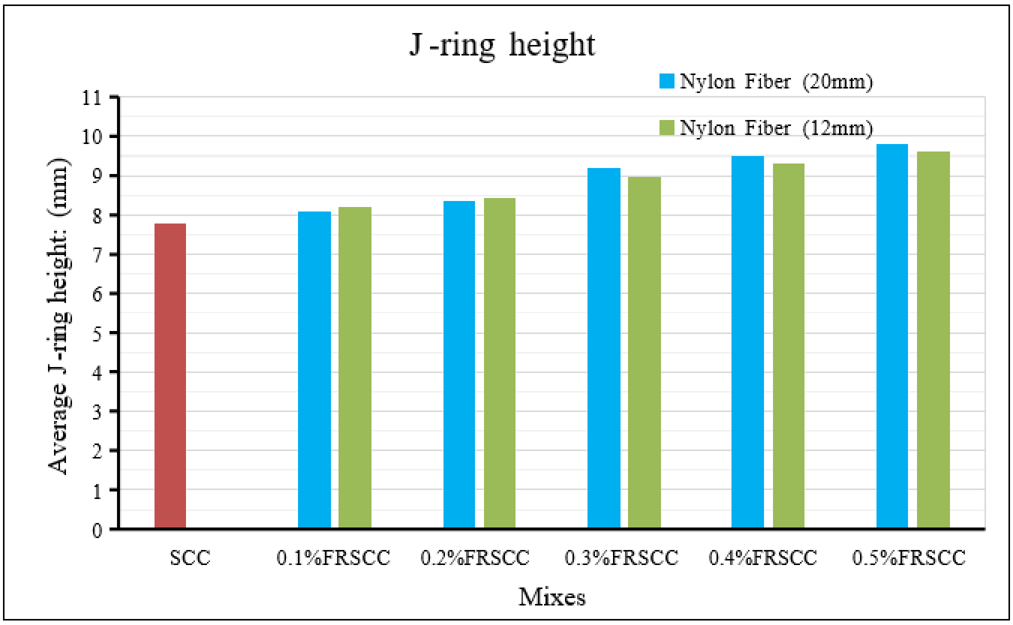

Figure 10. Effect of Nylon fiber on J-ring height of FRSCC

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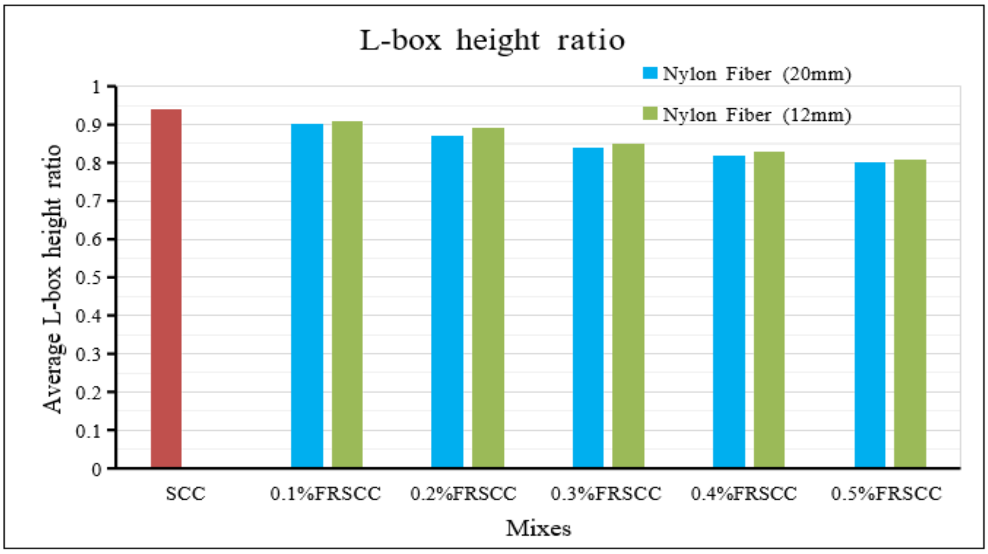

Figure 11. Effect of Nylon fiber on L-box height ratio of FRSCC

The results of fresh characteristics of both SCC and FRSCC with nylon fibres are shown in Table 3. The graphical views of slump flow time T50cm, slump flow diameter, V-funnel time, J-ring height, and L-box height ratio of controlled mix and mixes containing nylon fibres are shown in Figures 7 to 11. The results are also compared to a control mix that does not contain nylon fibres. The addition nylon fibres had a minor effect on all of the fresh qualities, as seen in the bar charts. In addition, the length of the fibre has a bigger impact on the workability of SCCs. The flow ability of FRSCC is depicted in Figures 7 to 9. The capacity of concretes to flow reduces as the length and volumetric proportion of NF increases, as seen in the figures. The combination with 0.5 percent NF and a 20mm length of NF had the greatest fall in workability values. Figures 10 and 11 depict FRSCC's ability to pass. The passage ability of concretes followed a similar pattern. Furthermore, according to EFNARC criteria, all of the fresh qualities of all of the mixtures with varying lengths and dosages of NF are within the permitted range.

3.2 Properties that have undergone a process of hardening

Compressive strength and spilt tensile strength were used to determine the toughened properties of SCC. For each mix, five standard-size cube and cylindrical specimens were cast and tested to determine the compressive and tensile strength of FRSCC with nylon fibres. After 24 hours of casting, all of the specimens were maintained at room temperature and demoulded. For wet curing, the specimens were dipped into a water tank. The specimens were tested when they were 28 days old. The cube and cylinder specimens were tested in a universal testing equipment to evaluate compressive and spilt tensile strength (UTM). Both the cube and cylinder specimens had their ultimate crushing strength measured. Figure 12 depicts a visual picture of the specimen being tested.

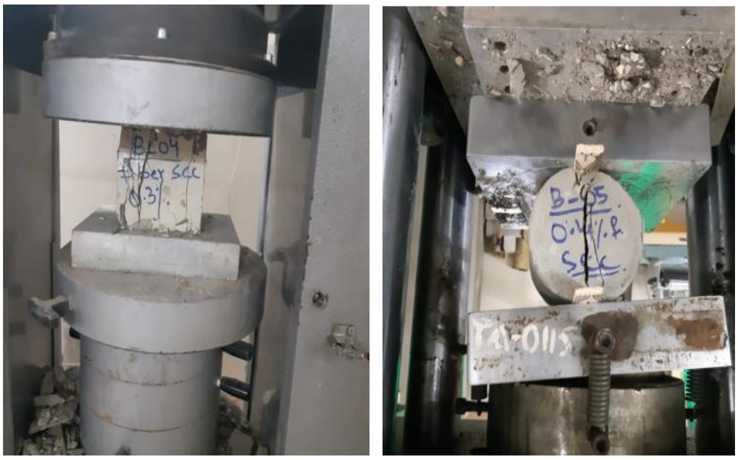

Figure 12. Pictorial view of cube and cylinder specimen at ultimate failure

Table 4. Strength properties of SCC and FRSCC

S. No.	Mixes	Compressive Strength (MPa)		Spilt Tensile Strength (MPa)	
		NF Length (20 mm)	NF Length (12 mm)	NF Length (20 mm)	NF Length (12 mm)
1	SCC	43.4		3.91	3.98
2	0.1% FRSCC	45.63	44.9	4.3	4.12
3	0.2% FRSCC	47.7	45.8	4.51	4.35
4	0.3% FRSCC	48.3	46.36	4.76	4.67
5	0.4% FRSCC	49.72	48.1	4.82	4.92
6	0.5% FRSCC	50.8	49.21	5.02	3.98

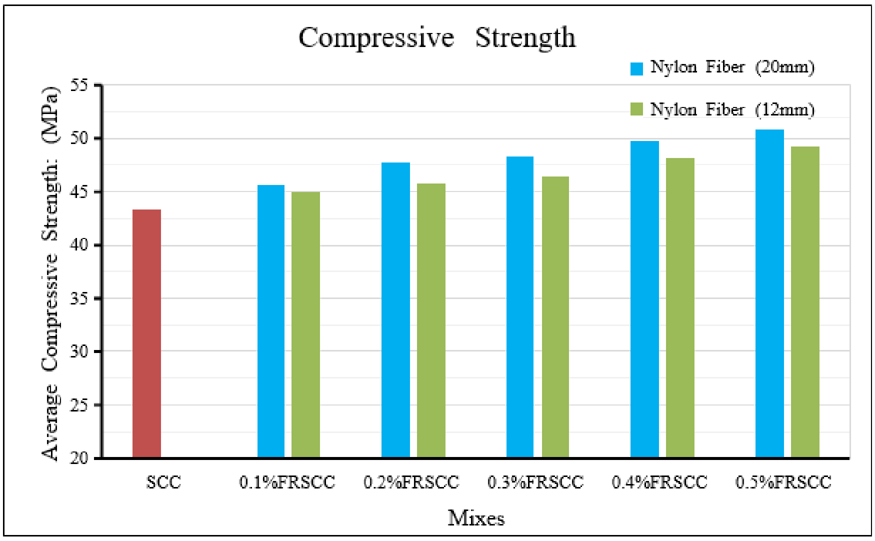

Figure 13. Effect of Nylon fiber on Compressive strength of FRSCC

Table 4 shows the average compressive and spilt tensile strengths of nylon fibre reinforced SCC. The graphical views of average compressive and spilt tensile strength are shown in Figures 13 and 14, respectively. At 28 days of curing, the compressive and spilt tensile strengths of the controlled mix were 43.4 and 3.91 MPa, respectively. As the volumetric proportion and length of fibres grow, the usage of NF in SCC increases both compressive and spilt tensile strength. This is because the flexibility of concrete improves when NF is added, delaying the creation of cracks when a load is applied. Hanif et al. (2017) [25] also addressed the similar trend results. At 20 mm length and 0.5 percent NF, the highest compressive strength was 50.8 MPa, and the spilt tensile strength was 5.02 MPa. The largest increase in compressive and tensile strength was found to be 17% and 28%, respectively. Additionally, the cube and cylinder specimens with nylon fibres did not entirely break into fragments upon crushing. The explanation for this is that fibres were used to connect the components of the sample. It's worth mentioning that the nylon fibre specimens offer a warning sign before they completely fail.

4. CONCLUSIONS

The following are the conclusions drawn from the findings.

- SCC and FRSCC have different fresh characteristics depending on the mix proportions, which can be modified by changing the SP dosage.
- According to EFNARC, the T50 test is a critical test for fresh qualities of SCC and FRSCC with NF, and T50 times between 2 and 5 seconds are regarded substitute values.
- The fresh characteristics of SCC are slightly influenced by the addition of NF. However, the magnitude of the influence is not large enough to be considered a significant factor.

Furthermore, the length of NF has an adverse effect on SCC's ability to pass. When making FRSCC mixtures using nylon fibres, the length and amount of NF used must be carefully considered. According to EFNARC criteria, all of the fresh property values for all of the mixes are within the required range. Similarly, the fresh characteristics of SCC and FRSCC with NF are affected by the length and proportion of NF. With the addition of NF, the compressive strength of FRSCC rises. At 20 mm length and 0.5 percent NF, the highest compressive strength was recorded. The largest increase in compressive strength compared to controlled concrete without NF is about 17%. The spilt tensile strength trended in the same direction. The highest increase in spilt tensile strength is approximately 28% of CM. It's worth mentioning that during ultimate load testing, the specimens with nylon fibres did not totally disintegrate. As a result, the warning time before complete failure is provided.

Declarations

Contributions of Authors

M.H.L., N.A.M., and M.A.M. were in charge of conceptualization; M.H.L., N.A.M., and M.A.M. were in charge of methodology; M.A.M. was in charge of formal analysis; M.H.L. and M.A.M. were in charge of resources; M.H.L. and M.A.M. were in charge of writing—original draught preparation; M.H The published version of the manuscript has been read and approved by all authors.

Statement of Data Availability

The corresponding author can provide the data used in this study upon request.

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Interest Conflicts

There are no conflicts of interest declared by the authors.

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