SELF COMPACTING CONCRETE WITH INCLUSION OF FIB: A COMPREHENSIVE INVESTIGATION

Y. P. Pawar[1] C. P. Pise[2] S. B. Pawar[3]

Article History: Received: 06.04.2023 **Revised:** 21.05.2023 **Accepted:** 06.07.2023

Abstract

Contrary to ordinary concrete, self-compacting concrete (SCC) flows under its own weight and doesn't require any effort to compact it. The only difference between SCC's ingredients and regular concrete's is that SCC uses more particles and Super Plasticizer. Fly ash, rice husk, and silica fume are examples of pozzolanic materials that are employed to assure the flowability of concrete. Due to the brittle nature of concrete, internal microcracks can form before it is loaded. If these cracks spread, the concrete may break. The use of synthetic, artificial, and natural fibres can stop concrete from cracking under tension. As a result, the addition of polypropylene and steel fibre to concrete is explored in this study along with its flexural strength and split tensile strength. For each combination, split tensile strength, and flexural strength, samples are created.

Keywords: Steel fibres, Polypropylene fibres, Self-compacting concrete; Flexural strength, Tensile strength, Fly ash,

---

[1]Research Scholar & Assistant Professor, SKN Sinhgad College of Engineering, Pandharpur, Maharashtra, India.
[2]Research Guide & Professor, SKN Sinhgad College of Engineering,Pandharpur, Maharashtra, India.
[3]Assistant Professor, SKN Sinhgad College of Engineering, Pandharpur, Maharashtra, India.

DOI: 10.31838/ecb/2023.12.s3.602

1. Introduction

The compacting effort is essential to the density and durability of the concrete. In order to build thick concrete with the required strength & toughness, vibrating energy must be applied in order to accomplish this purpose. Vibration, on the other hand, is among the major problems in the building industry. As a result, industry professionals kept stressing how important it was to produce concrete without vibrating. Long discussions have been had over this subject. Following the most significant studies and trials, self-compacting concrete was initially developed in Japan in 1980 [1]. The primary differences between self-compacting concrete and conventional concrete are, with the exception of the high smaller fines content at a low W/C ratio, which includes a higher range water reduction agent HWRA and viscosity modifying agents (VMA), the following:[2] The workability of fresh SCC is increased by adding mineral admixtures, such as GGBS, rice husk, silica fume, and fly ash (FA), among others. When pozzolanic material is utilised, the hydration reaction is prolonged and excellent structures are produced, increasing durability.[3] According to ACI 116R publications, "Fibre reinforced concrete" refers to concrete with irregular, randomly arranged fibres. Concrete cracks when subjected to tensile force because it is inherently weak in tension.[4] Steel, glass, natural, synthetic, and synthetic fibres, which are evenly distributed and randomly oriented, are among the components used in fibre reinforced concrete. The performance of fibre reinforced concrete is controlled by the type of material, aspect ratio, fibre characteristics, and fibre orientation. [5] Prior to loading, concrete develops internal microcracks; various studies have demonstrated that randomly oriented fibre can improve concrete performance. Concrete fractures are prevented from forming and spreading by fibre.[6] Polymer fibres are more lightweight, workable, and chemically stable than metallic fibre. Additionally, it has been discovered that polymeric fibres, in particular those made of polypropylene, are helpful in lowering shrinkage cracking and raising concrete's resilience to abrasion. According to the majority of testing findings, polypropylene can boost abrasion resistance by 30% to 60%. [7,8]. Investigations were done on the workability and mechanical characteristics of SCC reinforced with monofilament polypropylene fibres and fly ash. Four fibre contents at 3, 6, 9 and 12 kg/m3 were examined along with two cement concentrations at 350 and 450 kg/m^2.The fly ash concentration, the cement content, and the water/cement ratio were all kept constant at 0.40, 120 kg/m^3, and 1%, respectively. The fluidity, filling capacity, and segregation risk of the new concretes were assessed using the slump flow, J ring, V funnel, and air content tests. We calculated the concrete's unit weight, compressive strength, splitting tensile strength, flexural strength, pulse velocity, and elasticity modulus. When the distribution of the fibres is uniform, neither the materials utilised in this investigation nor their mixing or workability show any issues. The polypropylene fibres greatly increase SCC's strength without generating the well-known issues related to steel fibres[9].An experimental investigation examines the impact of specimen shape on the remaining mechanical characteristics of self-compacting concrete (SCC) made of polypropylene (PP) fibre that has been heated to temperatures between 200 and 600 0C. When concrete is subjected to thermal shock caused by air cooling from high temperatures up to 600 0C to room temperature, PP fibre can increase residual strength and fracture energy.[10] .Researchers on the basis of previously published results proposed distributed reinforcing of SC with polypropylene fibres of 6, 9, 12, and 15 mm in size and quantity from 0.5 to 2 kg per 1 m3 of concrete mixture in order to increase physical and mechanical qualities and durability, to deduce essential rules. According to the research, adding 1-2 kg per 1 m^3 of fibre with a 9–15 mm size improves the physical and technical characteristics of SCC, increasing its flexural strength by 10% and decreasing shrinkage deformations by 75% when compared to concrete without fibre. This study discovered that the manufacturing of SCC has more characteristics when low-modulus fibre is used as distributed reinforcement. In order to determine the best price-quality ratio and to enhance the quality of concrete works at high temperatures > 20 C, practical recommendations for the ideal size and quantity of fibre in SCC were offered based on the results.[11] In order to counteract the unfavourable brittleness of concrete and increase its tensile strength, PFs were added to concrete mixtures in amounts of 1.0%, 2.0%, 3.0%, and 4.0% by weight of cement. The mechanical performance (compressive and split tensile strength) was also assessed at 7, 14, and 28 days of curing. The fresh qualities were assessed based on their passing ability, flowability utilising the Slump flow, Slump T50 Spread time, L-Box, and V-funnel tests, as well as their mechanical performance. According to test results, the passing and filling capacity dropped as the PP substitution ratio rose. Additionally, the test results show that adding PP improved strength by up to 2.0% before gradually decreasing it. [12] In this investigation, the characteristics of self-compacting concrete (SCC) made with various ratios of recycled aggregates (RAs) and polypropylene fibres are compared to those of natural aggregates. In SCC, the effects of employing various ratios of natural aggregates (NAs) and polypropylene fibres (PPFs) of 0.1%, 0.2%, and 0.3% by volume of concrete in a fresh and hard condition were examined. There were a total of 20 mixture compositions. SCC testing in their uncured stage, such as Slump Flow, J Ring, V Funnel, and L Box, as well as hard concrete tests at age 28 days, such as compressive, tensile, flexural, and impact tests, are carried out. While increasing fibres generates a considerable drop in tests, increasing the usage of RAs has no impact on SCC tests in the fresh condition. Compressive strength, tensile strength, flexural strength, and impact resistance all decreased as more RAs of concrete were used in hardened concrete testing. The impact resistance, tensile strength, and energy absorption in the flexural test all increased as the proportion of polypropylene fibres in recycled concrete increased. [13]To learn more about the mechanical properties of FRSCC, a test programme is run. For this reason, the test programme takes into account four SCC mixes: simple SCC, steel, polypropylene, and hybrid FRSCC. Compressive stress-strain curve, elastic and rupture moduli, energy expended during compression, and compressive and splitting tensile strengths are among the characteristics. At 3, 7, 14, 28, 56, and 91 days, these characteristics are evaluated. In order to forecast the compressive and splitting tensile strengths, the elasticity and rupture moduli, the compressive stress-strain curve, and the energy lost during compression, relationships have been created. The predictions from the models are in line with the data.[14] With varied fibre types (steel and polypropylene) and quantities (0%, 0.25%, and 0.45% by volume), five FRSCC mixtures were created. To determine how fibres affect FRSCC behaviour, the fresh and mechanical properties of generated mixes, as well as their microstructure, were assessed. The findings indicated that adding more steel or polypropylene fibres reduces the workability of FRSCC, but the rheological properties of the put mixes met the European Guidelines for Self-Compacting Concrete guideline for fresh concrete. Additionally, by increasing the fibre content, the splitting tensile, flexural, and shear strengths were improved. use of epoxy injection and FRSC simultaneously. The suggested pullout models are straightforward, logical, and all-inclusive. The deformed reinforcing steel bars implanted in SCC and SFRSCC are covered by the suggested models' covered bond. The model's predictions and the experimental findings for both NSCC and HSCC, with and without various fibre volume reinforcements, were in excellent agreement. [15] This study examines how steel fibres affect the mechanical and physical characteristics of self-compacting concrete (SCC). Six distinct steel fibre reinforced self-compacting concrete (SFR-SCC) mixes were created, along with a control mix, with two different steel fibre aspect ratios (l/d) of 60 and 80 at three different volume fractions (Vf) of 0.35%, 0.45%, and 0.55%. A constant water-binder ratio of 0.34 and 2% cement additive silica fume (SF) were used in the casting of all specimens. Compressive strength, ultrasonic pulse velocity, rebound hammer, permeability, flexural strength, toughness, splitting tensile strength, and impact resistance of SCC were used to characterise the performance of several SCC specimens. The workability and rheology decrease as the steel fibre aspect ratio rises; the compressive strength of various SCC mixes varies slightly; the toughness, split tensile strength, and impact resistance increase; the ultrasonic velocity results rise; and the permeability results fall.[16]

2. Methodology

The following figure shows detailed methodology of the study.

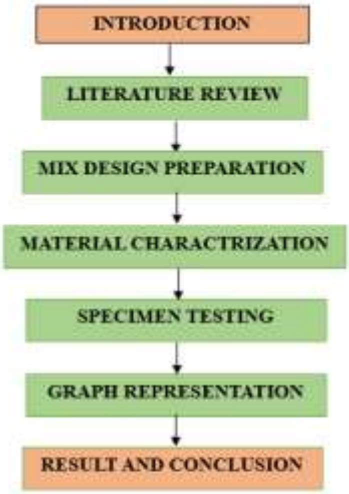


Figure 1. Detailed Methodology of the study

2.1. Characterisation of Material

Ordinary Portland Cement OPC 53 grade is used confirming IS:12269-1987, tests performed in accordance with IS:4031 (part IV)-1988.In accordance with ISO Standard 4031, Part II, 1999. Class F fly ash as per AST requirement C 618 IS:3812(Part 1): 2003 is used. Fine aggregate FA as natural sand of specific gravity of 2.78 is used, confirming ASTM C33 / C33M - 13 (2013). Coarse aggregate CA specific gravity 2.70 as per ASTM C33. Water confirming IS456:2000. Poly-Carboxylic Eather based super plasticizer SP supplied by Sika Viscocrete. Viscocity Modifying Agent VMA supplied by Sika Viscocrete .Hooked end Steel fibre of length 60 mm, Día 1.1 & aspect ratio 55.54 supplied by Dramax and virgin fibrillated polypropylene fibres of length 12 mm supplied by Dolphin India pvt. limited ,have been used for present experimental study.

Figure 2. Vergin farilited Polypropylyne Fibre

Figure 3. Hooked end steel fibre

2.2. Mix proportions

In present experimental study mix proportioning method developed by IS 10262:2019 is used for M50 concrete mix &W/C = 0.35. Normal Self Compacting Concrete NS, was produced without using fly ash. Cement by weight was partially replaced by fly ash by varying percentages. The mix in which cement was replaced by 35 % fly ash by weight was designated as control SCC. Table no.1 displays mix proportions of partial replacement of cement by fly ash. In control mix steel fibres & polypropylene fibres were added by percentage volume fraction of concrete. Workability properties of control SCC i.e. Passing ability & flow ability results were with in guide lines given by The European Federation for Specialised Construction Chemicals and Concrete Systems EFNARC. Marsh cone test was conducted to obtain optimum quantity of SP doses.

Table 1. Mix proportion for SCC mixes (per m3)

Mix	Cement kg/m3	Fly Ash	FA kg/m3	CA kg/m3	SP kg/m3	W/C	VMA kg/m3	WC kg/m3
NS	542	--	828	858.6	5.97	0.35	0.54	190
SccFly25	406.5	135.5	828	877.15	5.97	0.35	0.54	190
SccFly35	352.3	189.7	828	858.6	5.97	0.35	0.54	190

SccFly37.5	338.75	203.25	828	853	5.97	0.35	0.54	190
SccFly40	325.2	216..8	828	743.83	5.97	0.35	0.54	190
SccFly45	298.1	243.9	828	739.35	5.97	0.35	0.54	190
SccFly50	271	271	828	726.10	5.97	0.35	0.54	190

Table 2. Test information for cured concrete

Type of test	**Test Duration**	**Size details of cube**	**Test Refer code**
Split tensile strength	28th days	Cylinder size details: d =150 mm L= 300 mm	ASTM C496-96 IS:5816-1999
Flexural strength	28th days	100x 100 x 500 mm (Prism)	ASTM C78-94 IS:516-1959

Split Tensile Strength

Tensile strength is a measure that can be used to understand the physical properties of concrete in its hard state. Due to its weak tensile strength and brittleness, concrete is less likely than other materials to withstand the direct tension. Because a crack forms in the concrete member, the tensile strength of concrete must be determined. For the purpose of this investigation, Mix SccFly35 was chosen as the control SCC due to its cohesiveness, resistance to segregation, and mix that was produced without bleeding. In terms of split tensile strength and flexural strength, NS measured 5.72 N/mm2 and 8.84 N/mm2 correspondingly.

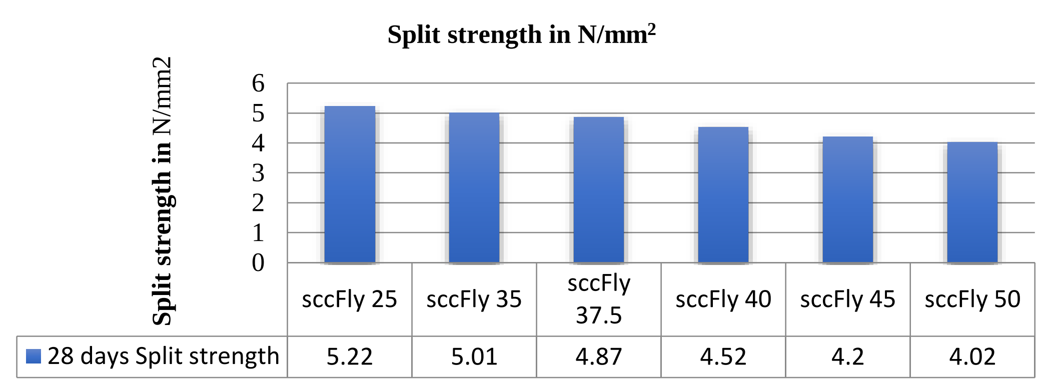


Figure 4. Split Tensile strength of different mixes in which cement is partially replaced by fly ash

Table 3. Polypropylene Fibre (PF) reinforced self-compacting concrete (PFscc)

Polypropylene fibre	**28 days split tensile strength**
SCC	5.01
PFscc1 (0.15 %)	5.61
PFscc2 (0.30 %)	6.23
PFscc3 (0.45 %)	6.51
PFscc4 (0.60 %)	6.7
PFscc5 (0.75 %)	6.10

Figure 5. Polypropylene Fibre (PF) reinforced self-compacting concrete (PFscc)

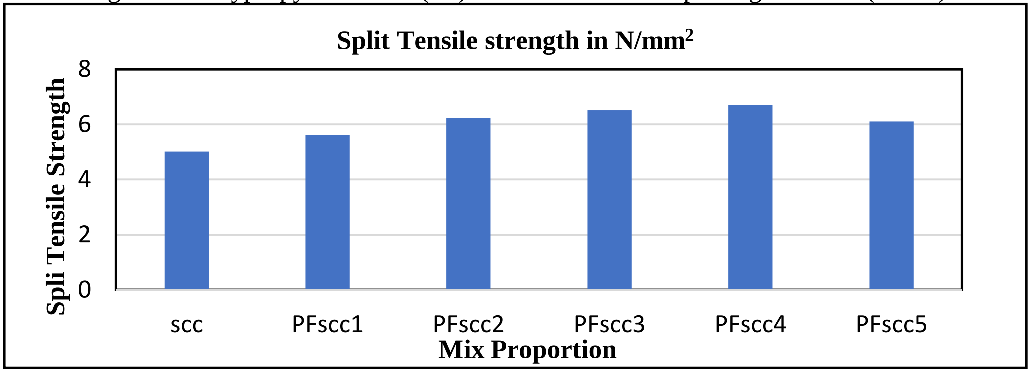


Table 4. Steel Fibre (SF) reinforced self-compacting Concrete in hardened state (SFscc)

Steel fibre	28 days split tensile strength
SCC	5.01
SFscc1 (0.25 %)	5.85
SFscc2 (0.50 %)	6.81
SFscc3 (0.75 %)	6.97
SFscc4 (1.0 %)	7.16
SFscc5 (1.25 %)	6.40

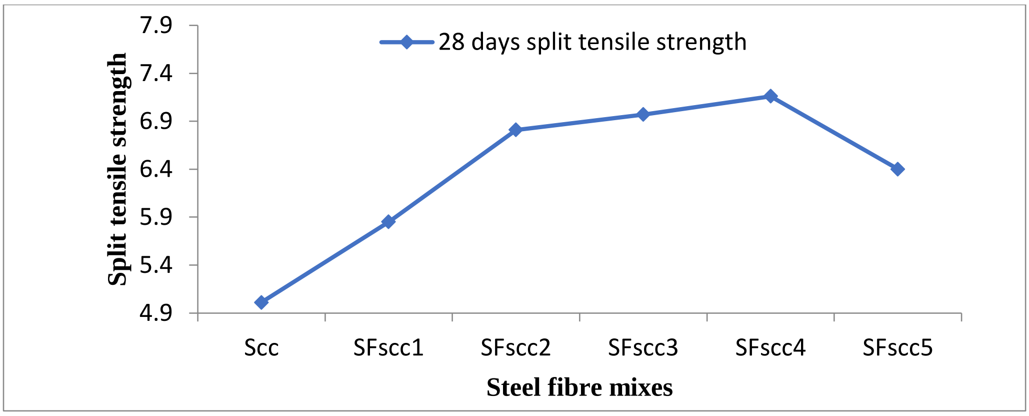


Figure.6 Steel Fibre (SF) reinforced self-compacting Concrete in hardened state (SFscc)

Table 5. Hybrid (Polypropylene + Steel) Fibre reinforced self-compacting concrete (HPSscc)

Hybrid fibre	28 days split tensile strength
SCC	5.01
HPSfscc1 (0.15 %+0.25 %)	6.01
HPSfscc2 (0.30 % +0.50%)	7.21
HPSfscc3 (0.45 %+ 0.75%)	8.23
HPSfscc4 (0.60%+ 1.0%)	8.49
HPSfscc5 (0.75 % +1.25%)	7.91

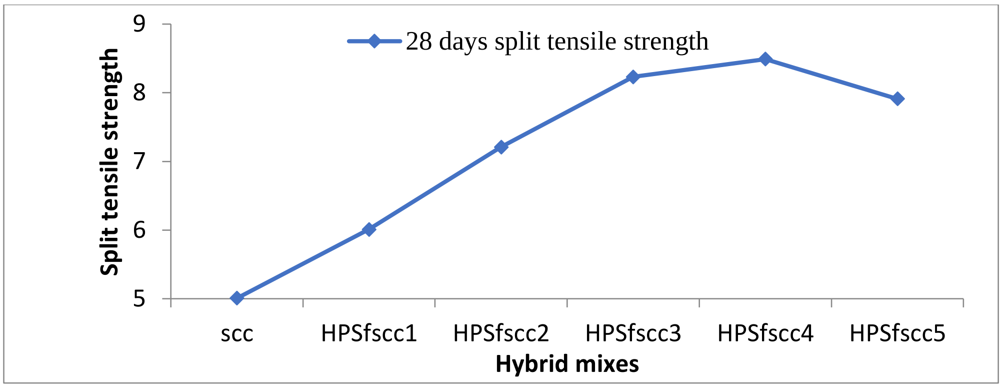


Figure.7 Hybrid (Polypropylene + Steel) Fibre reinforced self-compacting concrete (HPSfscc)

Flexural Strength

The goal of the flexure test is to determine the concrete's flexural strength under tension. Additionally, the flexure test is simpler to do and might perhaps be more practical than the crushing test

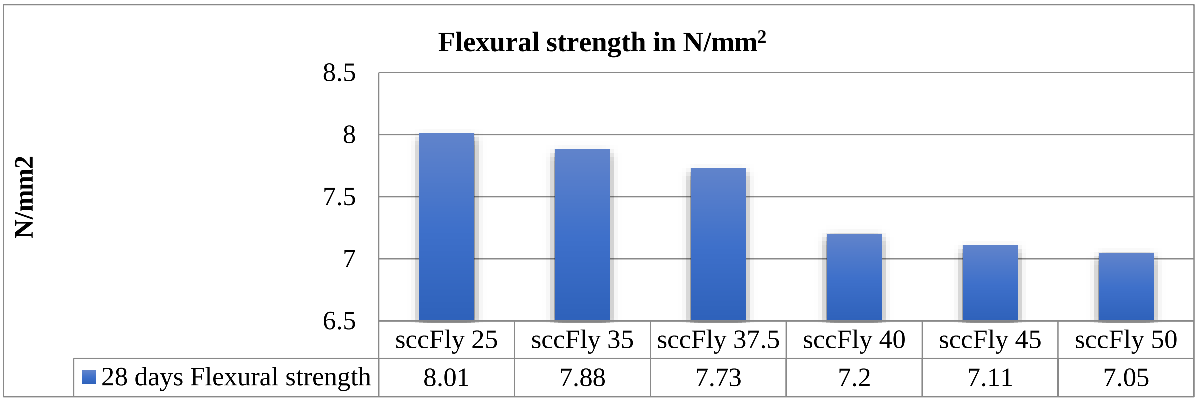


Figure 8. Flexural strength of different mixes in which cement is partially replaced by fly ash

Table 6. Polypropylene Fibre (PF) reinforced self-compacting concrete (PFscc)

Polypropylene fibre	**28 days flexural strength**
SCC	7.88
PFscc1 (0.15%)	9.01
PFscc2 (0.30%)	9.38
PFscc3 (0.45%)	10.44
PFscc4 (0.60%)	9.57
PFscc5 (0.75%)	9.11

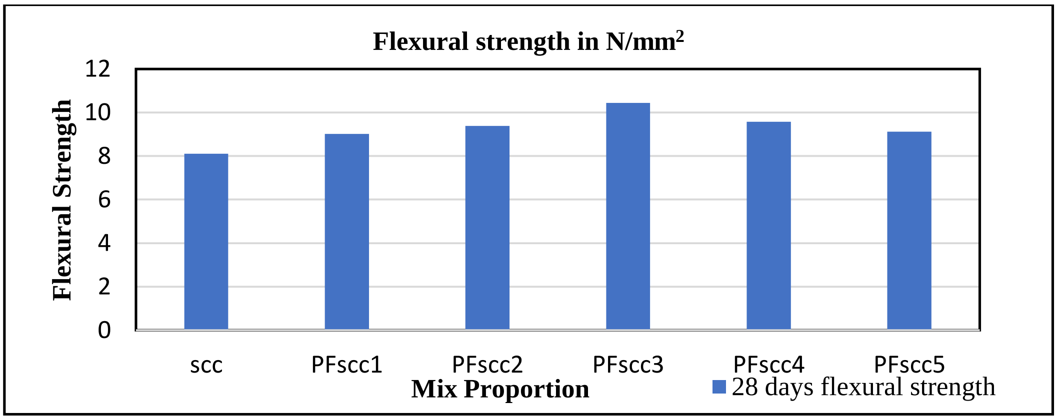


Figure 9. Flexural strength vs PF fibre addition to Control SCC

Table 7. Steel Fibre (SF) reinforced self-compacting Concrete in hardened state (SFscc)

Steel fibre	**28 days flexural strength (N/mm^2)**
SCC	7.88
SFscc1 (0.25%)	10.21
SFscc2 (0.50%)	11.66
SFscc3 (0.75%)	13.06
SFscc4 (1.0%)	14.52
SFscc5 (1.25%)	13.50

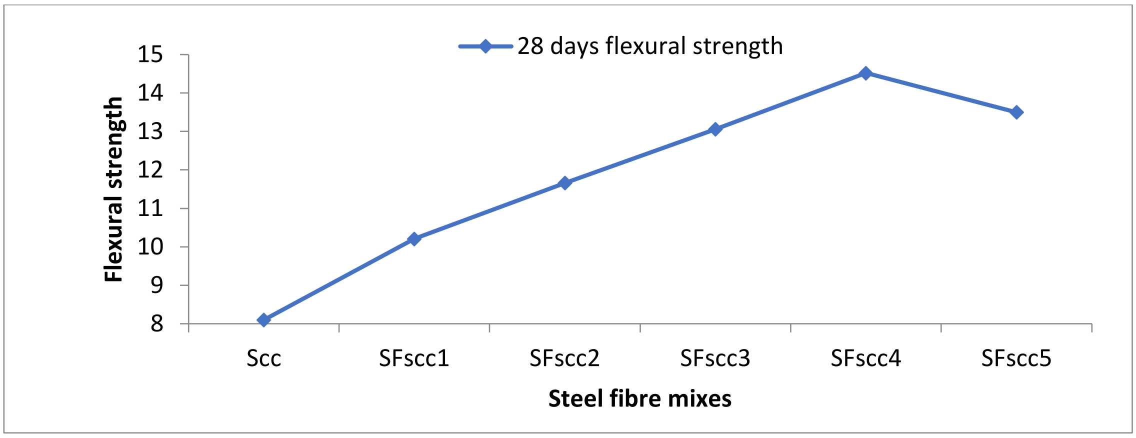
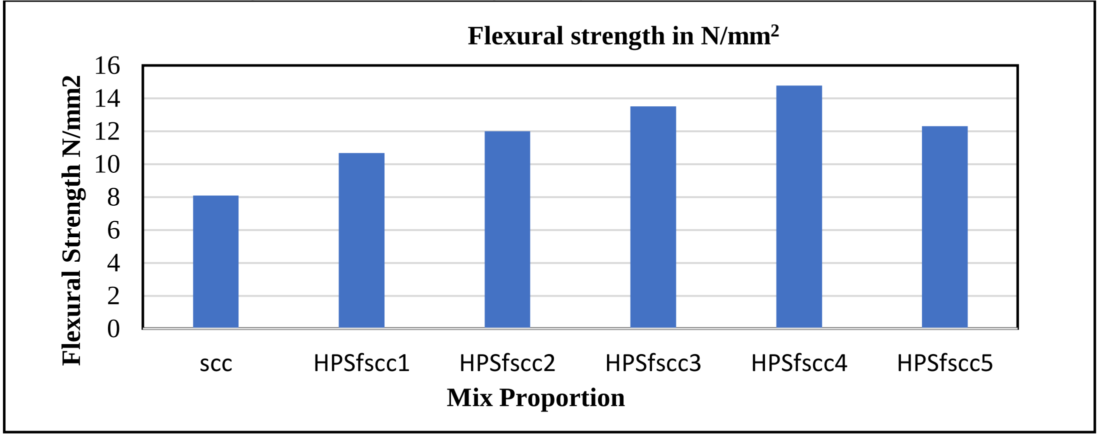


Figure 10. Steel Fibre (SF) reinforced self-compacting Concrete in hardened state (SFscc)

Table 8. Hybrid (Polypropylene + Steel) Fibre reinforced self-compacting concrete (HPSscc)

HPSfscc	**28 days flexural strength**
SCC	7.88
HPSfscc1 (0.15% +0.25%)	10.68
HPSfscc2 (0.30%+0.50%)	11.99
HPSfscc3 (0.45%+0.75%)	13.51
HPSfscc4 (0.60%+1.0%)	14.78
HPSfscc5 (0.75%+1.25%)	12.31

Figure 11. Flexural strength vs Hybrid Fibre addition to SCC



Summary and Conclusions

General

After the SCC specimens had been cast, cured, and tested, the test findings were examined. This article goes into detail about the conclusions reached based on the research survey results.

3. Conclusions

1. It has been noted that split tensile strength and flexural strength gradually decrease as NS when 25%, 35%, 37.5%, 40%, 45%, and 50% of the cement in a kilogramme are substituted by fly ash. as depicted in figures 4 and 8.
2. When PP fibre is added in amounts of 0.15%, 0.30%, 0.45%, and 0.60% to the control SCC shown in Table 3 and Figure 5, the split tensile strength is raised by 11.97%, 24.35%, 29.94%, and 33.93% higher than the control SCC. According to Table 6 and Figure 9, the addition of 0.15%, 0.30%, and 0.45% of PP fibre enhanced flexural strength by 11.23%, 15.80% and 28.88% higher than the control SCC.
3. According to Table 4 and Figure 6, adding 0.25%, 0.50%, 0.75%, and 1.0% of steel fibre to the mix increased split tensile strength by 16.76%, 35.92%, 39.12%, and 42.91%, respectively, over Control SCC. Similar to this, adding 0.25%, 0.50%, 0.75%, and 1.0% of steel fibre increases flexural strength by 26.04%, 43.95%, 61.23%, and 75.25% compared to Control SCC, as shown in Table 7 and Figure 10.
4. When 0.15% + 0.25% hybrid fibre is introduced, split tensile strength is 19.96% higher than control SCC. Additionally, it has increased by 30.92%, 64.27%, and 60.92% compared to the control SCC for further addition of hybrid fibers respectively. When 0.75%+1.25% hybrid fibre is added to Control SCC, the rate of growth in split tensile strength is reduced to 57.88% as that of Control SCC, as shown in Table 5 & Figure 7. Similar to how the flexural strength of control concrete is raised by percentage volume fractions of 0.30% + 0.50%, 0.45% + 0.75%, and 0.60% + 1.0%, the flexural strength of hybrid concrete is improved by 48.02%, 66.79%, and 84.31% respectively. According to Table 8 and Figure 11, the rate of improvement in flexural strength is reduced for fibre additions of 0.75%+1.25%.
5. Workability, which directly influences strength, is observed to decline as the percentage of fibres in concrete increases. As a result, it is discovered that the strength of the concrete first increases & decreases as the amount of fibres increases. Beyond 35 % cement replacement strengths decreases rapidly, it may be because of most of the fly ash remains unreacted, it does not form additional calcium silicate hydrate.
6. It has been discovered that the strength of a mixture of fibres increases greater than the strength of a single fibre.

4. References

Okamura, H. Self-Compacting High-performance Concrete. Concrete International. 1997. 19(7). Pp. 50–54.

Ahmad, S., & Umar, A. (2018). Fibre-reinforced self-compacting concrete: a review. In IOP Conference Series: Materials Science and Engineering (Vol. 377, No. 1, p. 012117). IOP Publishing.

Khayat, K. and G. De Schutter (2013). "Mechanical Properties of Self-Compacting Concrete." State-or-the-art report of RILEM Technical Committee 228-MPS.

Ivanauskas, Z. Rudzionis, A. A. Navickas and M. Dauksys: 'Investigation of shale ashes influences on the self-compacting 17 Relative comparison of A–F, B–G, C–H, D–K and E–L concrete pairs Gencel et al. Mechanical properties of SCC reinforced with PP fibres Materials Research Innovations 2011 VOL 15 NO 3

W. Brostow, H. E. Hagg Lobland and M. Narkis: 'Sliding wear, viscoelasticity and brittleness of polymers', J. Mater. Res., 2006, 21 , 2422–2428. 20.

W. Brostow and H. E. Hagg Lobland: 'Brittleness of materials: implications for composites and relation to impact strength', J. Mater. Sci., 2010, 45, 242–250. 21. D. J. Hannant: 'Fibre cement and fibre concrete'; 1987, Chichester

Nobili, A., L. Lanzoni, et al. (2013). "Experimental investigation and monitoring of a polypropylene-based fibre reinforced concrete road pavement." Construction and Building Materials 47: 888-895.

Shuan-fa, C. (2001). "The Concrete Flexural Fatigue Property by Adding Polypropylene Fibre [J]." Journal of Xi'an Highway University 2: 005.

Mechanical properties of self-compacting concrete reinforced with polypropylene fibres.

Materials Research Innovations · June 2011 DOI: 10.1179/143307511X13018917925900

Daniyar Akhmetov a et.al Effect of low-modulus polypropylene fibre on physical and mechanical properties of self-compacting concrete Case Studies in Construction Materials 16 (2022) e0081

Jawad Ahmad*, Fahid Aslam, Osama Zaid, Rayed Alyousef, Hisham Alabduljabbar, and Aneel Manan Self-Fibres Compacting Concrete Properties Reinforced with Propylene Fibres Sci Eng Compos Mater 2021; 28:64–72 Research Article

Influence of polypropylene-fibre on the mechanical properties of self-compacting-concrete with recycled aggregates M. Hajmohammadian

Baghba a , S.A.H. Hashemib *, K. Kalbasi Anarakib , E.S. Hashemic Magazine of Civil Engineering. 2020. 99(7). Article No. 9905 DOI: 10.18720/MCE.99.5

Farhad Aslani, Shami Nejadi Self-compacting concrete incorporating steel and polypropylene fibers: Compressive and tensile strengths, moduli of elasticity and rupture, Composites: Part B 53 (2013) 121–133

Farhad Aslani, Shami Nejadi ,Bond characteristics of steel fibre and deformed reinforcing steel bar embedded in steel fibre reinforced self-compacting concrete (SFRSCC) Cent. Eur. J. Eng. • 2(3) • 2012 • 445-470 DOI: 10.2478/s13531-012-0015-3 Central European Journal of Engineering

Mohammed A. Abed ,Jan Foˇrt , Abdulkarim Naoulo and Amr Essa

Influence of Polypropylene and Steel Fibres on the Performance and Crack Repair of Self-Compacting Concrete . Materials 2021, 14, 5506. https://doi.org/10.3390/ma14195506

Anas Alrawashdeh , Ozgur Eren Mechanical and physical characterisation of steel fibre reinforced self-compacting concrete: Different aspect ratios and volume fractions of fibres . Results in Engineering 13 (2022) 100