

A Study On Mechanical And Rheological Properties Of Hybrid Fibre Reinforced Self Compacting Concrete

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ABSTRACT

Self-compacting concrete (SCC) is designed to flow and consolidate under its own weight, but the addition of fibres can change both fresh-state workability and hardened mechanical performance. This experimental study investigated M30 SCC reinforced with hybrid steel and polypropylene fibres. The programme included material characterization, SCC mix design, slump-flow and T500 testing, L-box and V-funnel testing, and compressive-strength testing of 150 × 150 × 150 mm cubes. The designed SCC used 312.9 kg/m³ cement, 926.5 kg/m³ fine aggregate, 910.299 kg/m³ coarse aggregate, 192 kg/m³ water, 0.6% PCE superplasticizer, and 0.3% VMA, with slag reported in the designed mixture. Slump flow was 620, 644, 650, 609, and 600 mm for the fibre additions reported from 0 to 1%, with the highest reported slump at 0.5%. L-box ratios ranged from 0.82 to 0.98 and V-funnel times from 6.8 to 8.7 s. For the designed M30 concrete, average compressive strength increased with the reported fibre level at 3, 7, 21, and 28 days; the maximum 28-day value was 39.11 N/mm² at 2% fibre. The thesis concludes that 1.5% hybrid fibre content provided the best balance between strength enhancement and workability.

Keywords: Self-compacting concrete; Hybrid fibres; Steel fibre; Polypropylene fibre; Rheological properties; Compressive strength

I. INTRODUCTION

Self-compacting concrete was developed to achieve filling and consolidation without external vibration, making it useful where reinforcement is congested or formwork is difficult to access. Its performance is controlled by flowability, deformability, viscosity, passing ability, and resistance to segregation. The thesis identifies SCC as a means of improving placement quality while reducing dependence on vibration and manual compaction [21]-[25].

The hardened behaviour of SCC can remain limited by tensile weakness, brittleness, and microcracking. Hybrid fibre reinforcement combines fibres with different mechanical roles. In the thesis, steel fibres are associated with crack bridging, strength, and toughness, while polypropylene fibres are associated with shrinkage-crack control, ductility, and durability. Previous studies reviewed in the thesis reported that hybrid steel-polypropylene systems can improve mechanical performance and crack control, although increasing fibre content can reduce workability [8], [15], [16].

The research problem is therefore the need to identify a fibre dosage that improves hardened performance without causing an unacceptable loss of SCC flow and passing ability. The present article condenses the thesis experimental programme and retains the fresh-property and compressive-strength evidence used to address this balance.

II. OBJECTIVES

- To investigate fresh properties of SCC.
- To evaluate influence of Hybrid Fibres on Mechanical properties.
- To compare performance analysis of SCC with Hybrid Fibres.
- To determine the optimum percentage of hybrid fibre content for achieving improved strength and workability in Self-Compacting Concrete.

III. LITERATURE SURVEY

The thesis literature review covers SCC mix design, mineral and chemical admixtures, and fibre reinforcement over a wide range of studies. Pathan et al. addressed predictive strength modelling for SCC containing steel and polypropylene fibres [1], while Donmez et al. examined sustainable hybrid-fibre SCC with blended binders [4]. Khan et al. reported improved toughness and microcrack control with polypropylene-containing hybrid systems [8].

Yoo and Banthia described complementary roles for steel and polypropylene fibres, with steel fibres improving load transfer and post-cracking resistance and polypropylene fibres supporting shrinkage control and toughness [15]. Afroughsabet and Ozbakkaloglu likewise reported improved mechanical and durability performance for concrete containing steel and polypropylene fibres [16]. The broader SCC literature cited in the thesis emphasizes that fibre addition can enhance crack resistance while simultaneously reducing fresh flow, making dosage optimization essential [21]-[25].

IV. MATERIALS AND METHODOLOGY

Experimental programme

The experimental sequence comprised literature review, material selection, material testing, M30 SCC mix design, specimen preparation, casting and curing, fresh-property testing, compressive-strength testing, and comparative interpretation. OPC 53-grade cement, fine aggregate, coarse aggregate, laboratory water, PCE superplasticizer, VMA, steel fibre, and polypropylene fibre were used. PCE and VMA dosages were reported as 0.6% and 0.3%, respectively.

Table 1. Key constituent and fibre properties reported in the thesis

Constituent / property	Reported value
Cement	OPC 53 grade; specific gravity reported as 3.16 in materials section
Fine aggregate	Fineness modulus 2.83; specific gravity 2.69; water absorption 1%; bulk density 1700 kg/cum
Coarse aggregate	10–12 mm selected; specific gravity 2.69; water absorption 0.6%; impact value 23.3%; crushing value 24.02%
PCE superplasticizer	0.6%
VMA	0.3%
Steel fibre	Length 13 mm; diameter 0.22–0.35 mm; aspect ratio 20–30; tensile strength reported as 2000m2
Polypropylene fibre	Specific gravity 0.91; length 50 mm; tensile strength >600 MPa; Young's modulus >6 GPa; aspect ratio >45

M30 SCC mix design

The thesis mix design was prepared for M30 concrete with a target strength of 38.25 N/mm². The selected free water-cement ratio was 0.43. The designed material quantities are reproduced below exactly from the thesis mix table; the report also lists a powder content of 516 kg/m³ and a water-powder volume ratio of 1.08.

Table 2. Materials required in kg/m³ of concrete (thesis Table 5.2)

Material	Conventional concrete	Designed mix (M-30)
Cement	490	312.9
Slag	-	89.4
Fine Aggregate	932	926.5
Coarse Aggregate	880	910.299
Water	161	192
Superplasticizer (0.6%)	-	1.8774
VMA (0.3%)	-	0.9387

Specimen preparation and testing

Concrete was mixed, placed in prepared moulds, compacted as described in the thesis casting procedure, demoulded after approximately 24 hours, and water-cured for 3, 7, 21, and 28 days. Compressive strength was tested on 150 × 150 × 150 mm cubes using a 1000 kN compression testing machine following the thesis-stated IS 516–1959 procedure. Compressive strength was calculated using $f_{ck} = P/A$, where P is the ultimate compressive load and A is the specimen cross-sectional area.



Fig. 1. Compressive-strength testing machine retained from the thesis.



Fig. 2. Compressive testing of cubes retained from the thesis.

V. RESULTS AND DISCUSSION

Fresh properties

The slump-flow test was used to evaluate filling ability and T500 time, the L-box test was used to assess passing ability, and the V-funnel test was used to characterize flow time. The complete thesis values are retained in Tables 3–5.

Table 3. Slump-flow test results (thesis Table 6.1)

Fiber Addition (%)	Slump Flow (mm)	T-500 Test (seconds)
0%	620	2.22
0.25%	644	2.54
0.5%	650	3.00
0.75%	609	3.24
1%	600	3.85

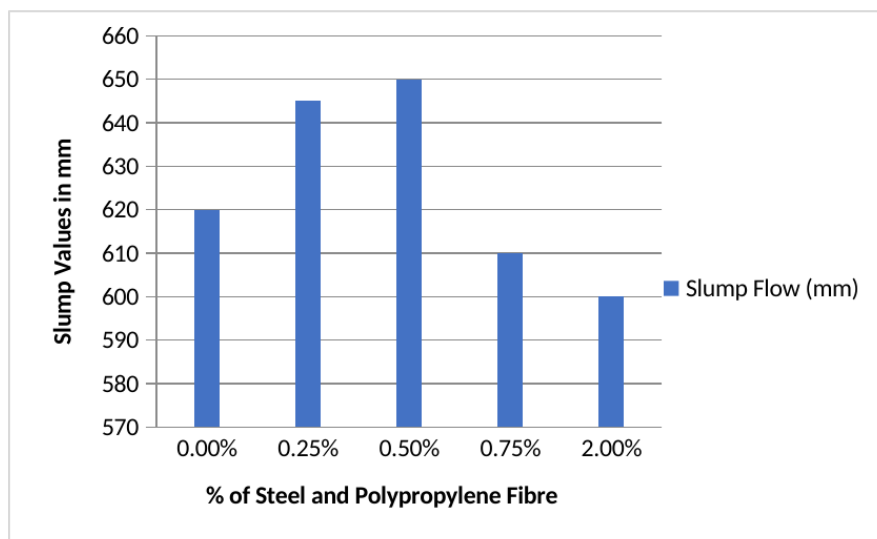


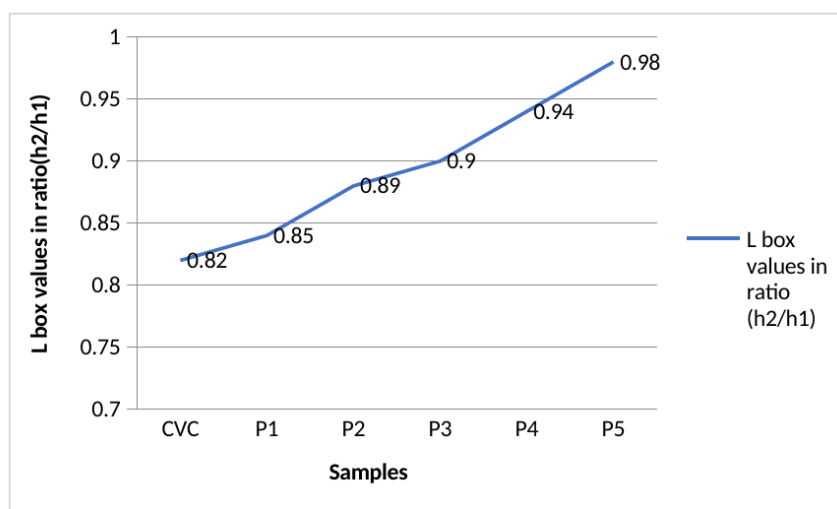
Fig. 3. Original thesis Graph 6.1: Slump Flow V/S Various Percentage of Fibres.

The source table reports a maximum slump flow of 650 mm at 0.5% fibre addition, followed by lower values at 0.75% and 1%. The thesis conclusion identifies 0.5% as the optimum slump condition before a significant reduction in workability. The original Graph 6.1 labels its final category as 2.00%, whereas Table 6.1 reports the final fibre addition as 1%; both source representations are retained without alteration.

Table 4. L-box test results (thesis Table 6.2)

Sl. No	Samples	L box values in ratio (h2/h1)
1	CVC	0.82
2	P1	0.85
3	P2	0.89
4	P3	0.9
5	P4	0.94
6	P5	0.98

Graph No 6.2: L-Box values V/S Various % of Fibres



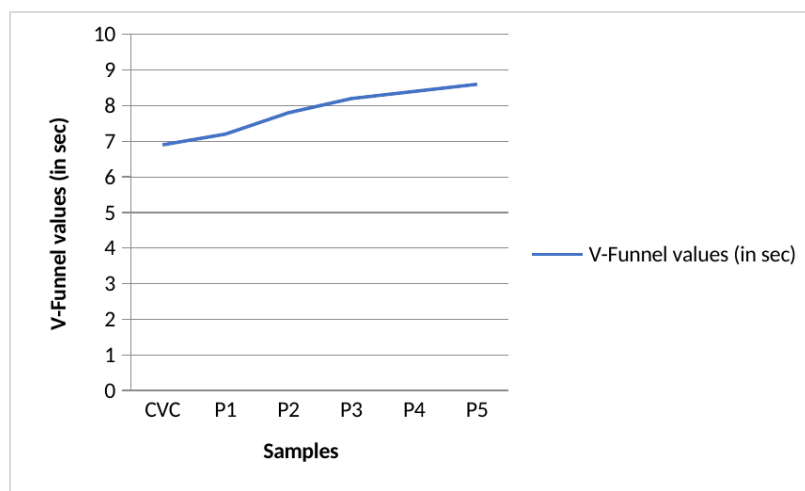
V Funnel:

Fig. 4. Original thesis Graph 6.2: L-Box values V/S Various % of Fibres.

All reported L-box ratios were greater than 0.8, increasing from 0.82 for CVC to 0.98 for P5. The thesis interprets these values as indicating excellent passing ability across the tested samples.

Table 5. V-funnel test results (thesis Table 6.3)

Sl. No	Samples	V-Funnel values (in sec)
1	CVC	6.8
2	P1	7.3
3	P2	7.9
4	P3	8.3
5	P4	8.5
6	P5	8.7

Graph No 6.3: V-Funnel Test

Fig. 5. Original thesis Graph 6.3: V-Funnel Test.

The reported V-funnel time increased from 6.8 s for CVC to 8.7 s for P5. The thesis states that flow time remained within acceptable limits up to 0.5% fibre content and increased at higher fibre percentages. The source methodology text also mentions a value below 6 s as a qualification criterion; the article preserves the reported data and thesis interpretation without recalculation or substitution.

Compressive strength

The conventional-concrete results establish the comparison across curing periods. The thesis reports average compressive strengths of 14.535, 24.481, 34.040, and 38.630 N/mm² at the N3, N7, N21, and N28 identifications.

Table 6. CVC compression values (thesis Table 6.4)

Sl. No	Identification	X-sectional area (m2)	Average Compressive Strength (N/mm ²)
1	N3	22500	14.535
2	N7	22500	24.481
3	N21	22500	34.040
4	N28	22500	38.630

Graph No 6.4: CVC Compression Strength Output

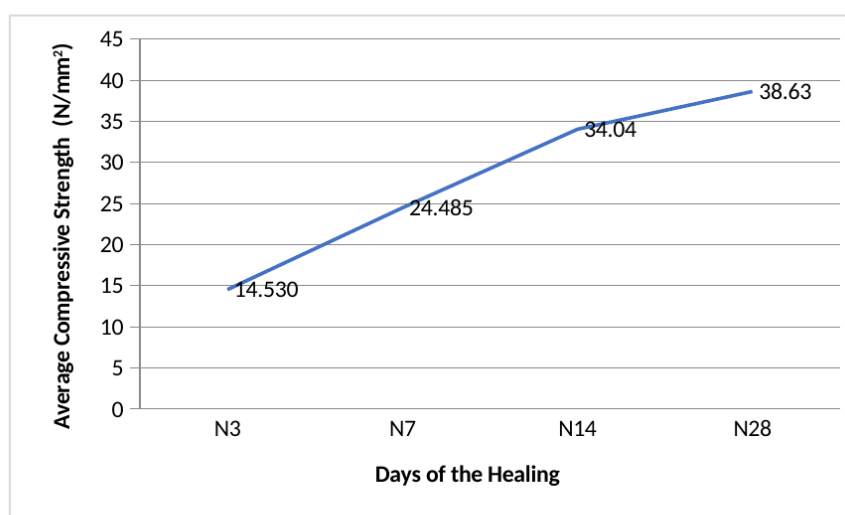


Fig. 6. Original thesis Graph 6.4: CVC Compression Strength Output.

Table 7. Compression Test Output at 3 days curing

Sample No.	Silica Fume, Slag, Various % Of Steel And Polypropylene	Cube 1 (N/mm ²)	Cube 2 (N/mm ²)	Average (N/mm ²)
P1	0 %	13.386	13.579	13.482
P2	0.5 %	13.76	13.975	13.865
P3	1 %	14.245	14.337	14.291
P4	1.5 %	14.646	14.765	14.696
P5	2 %	15.148	15.168	15.158

Graph No 6.5: Average Compressive Strength at 3 days

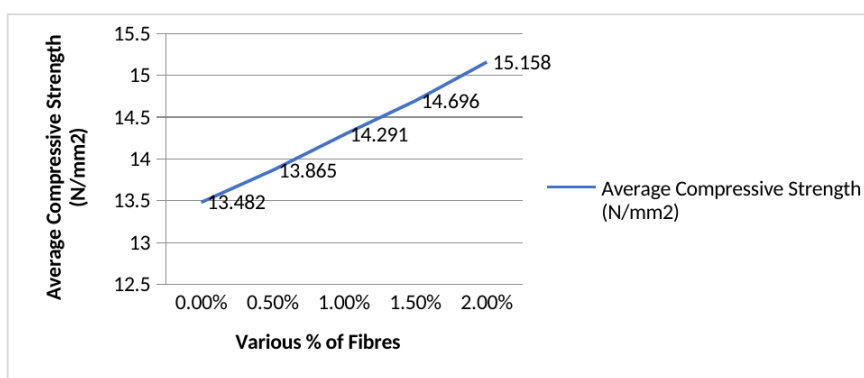


Fig. 7. Original thesis average compressive-strength graph at 3 days curing.

Table 8. Compression Test Output at 7 days curing

Sample No.	Silica Fume, Slag, Various % Of Steel And Polypropylene	Cube 1 (N/mm ²)	Cube 2 (N/mm ²)	Average (N/mm ²)

P1	0 %	23.10	23.35	23.23
P2	0.5 %	23.65	23.87	23.76
P3	1 %	24.10	24.35	24.23
P4	1.5 %	24.60	24.85	24.73
P5	2 %	25.00	25.25	25.13

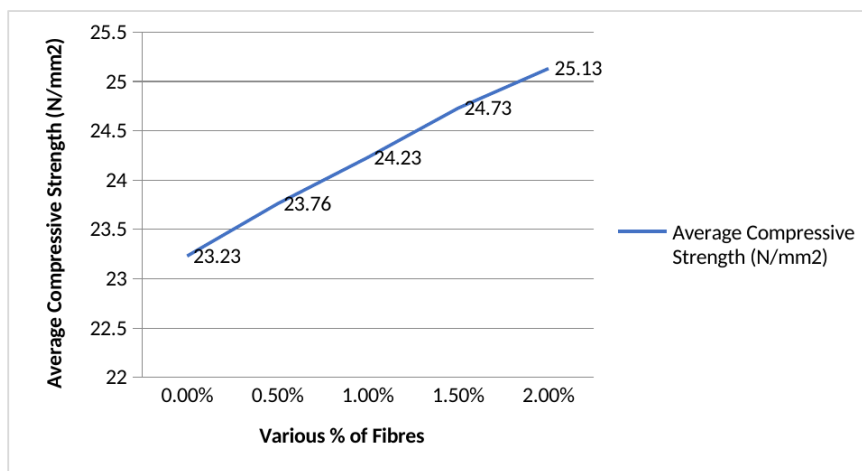


Fig. 8. Original thesis average compressive-strength graph at 7 days curing.

Table 9. Compression Test Output at 21 days curing

Sample No.	Silica Fume, Slag, Various % Of Steel And Polypropylene	Cube 1 (N/mm²)	Cube 2 (N/mm²)	Average (N/mm²)
P1	0 %	33.10	33.40	33.25
P2	0.5 %	33.50	33.80	33.65
P3	1 %	34.00	34.25	34.13
P4	1.5 %	34.50	34.80	34.65
P5	2 %	35.00	35.25	35.13

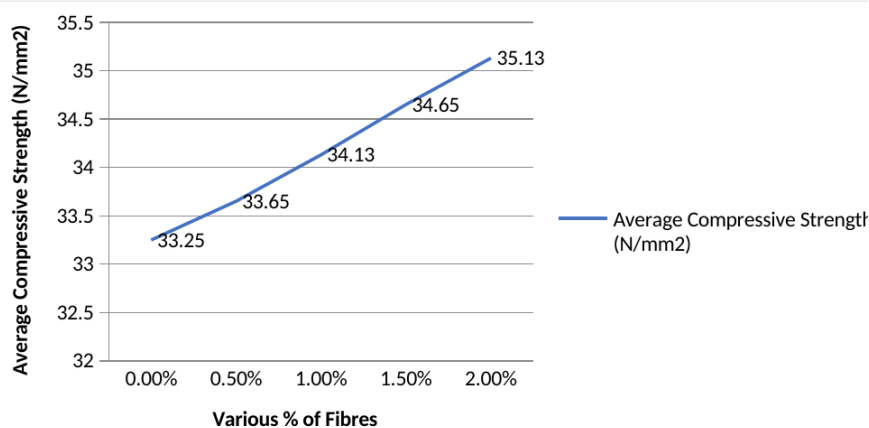


Fig. 9. Original thesis average compressive-strength graph at 21 days curing.

Table 10. Compression Test Output at 28 days curing

Sample No.	Silica Fume, Slag, Various % Of Steel And Polypropylene	Cube 1 (N/mm ²)	Cube 2 (N/mm ²)	Average (N/mm ²)
P1	0 %	37.485	37.73	37.61
P2	0.5 %	37.867	38.077	37.97
P3	1 %	38.25	38.441	38.35
P4	1.5 %	38.632	38.842	38.74
P5	2 %	39.015	39.206	39.11

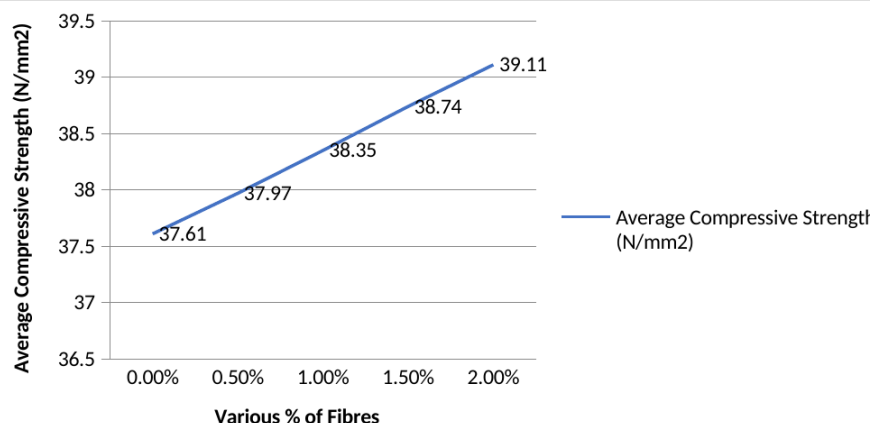


Fig. 10. Original thesis average compressive-strength graph at 28 days curing.

For the designed M30 series, the reported average strength increased progressively from P1 to P5 at each curing age. At 3 days the averages ranged from 13.482 to 15.158 N/mm²; at 7 days from 23.23 to 25.13 N/mm²; at 21 days from 33.25 to 35.13 N/mm²; and at 28 days from 37.61 to 39.11 N/mm². The maximum reported 28-day compressive strength was 39.11 N/mm² for P5 at 2% fibre.

The thesis concludes that hybrid-fibre SCC had higher compressive strength than conventional concrete over the reported curing periods and that early strength development improved with hybrid fibres. Although the maximum strength was recorded at 2%, the thesis identifies 1.5% as the optimum hybrid fibre content when workability and strength are considered together.

VI. CONCLUSION

- Slump Flow, L-Box, and V-Funnel testing was used to assess the fresh behaviour of the SCC mixes, and the thesis reports satisfactory flowability and passing ability for the designed SCC.
- Slump flow reached its highest reported value of 650 mm at 0.5% fibre addition and decreased at higher fibre additions in Table 6.1.
- L-box ratios ranged from 0.82 to 0.98, and the thesis interprets all reported values as indicating good passing ability.
- V-funnel time increased from 6.8 to 8.7 s across the reported samples, indicating increasing resistance to flow with fibre addition.
- The designed M30 series showed increasing compressive strength with the reported fibre level at 3, 7, 21, and 28 days.
- The maximum reported compressive strength was 39.11 N/mm² at 28 days for the 2% hybrid-fibre condition.
- The thesis identifies 1.5% hybrid fibre content as the optimum level for balancing strength improvement with workability.
- The combined use of steel and polypropylene fibres is concluded in the thesis to assist microcrack control and improve the performance of SCC for structural applications.

Source-data notes

This article is a conversion of the supplied thesis. Numerical values, test labels, graph content, and stated conclusions have been retained from that source. Where the thesis contains internal label or criterion inconsistencies, the article does not replace them with externally inferred values.

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