

Study On Physical Properties Of Hybrid Fibres Reinforced Self Compacting Concrete

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ABSTRACT

Self-Compacting Concrete (SCC) can fill congested reinforced sections without external vibration, but brittle behavior, shrinkage cracking, pore formation, and water penetration may limit long-term performance. This study investigated the fresh and physical/durability properties of M40 Hybrid Fiber Reinforced Self-Compacting Concrete (HFRSCC) containing steel and polypropylene fibers at total volume fractions of 0%, 1%, 1.25%, 1.5%, and 1.75%. The mixes used OPC 53 grade cement, fly ash, GGBS, fine and coarse aggregates, superplasticizer, and viscosity-modifying admixture. Fresh performance was evaluated by slump flow/T500, V-funnel, and L-box tests. Hardened properties included density, water absorption, porosity, permeability, and drying shrinkage. Increasing fiber content reduced slump flow from 780 to 640 mm and the L-box ratio from 0.97 to 0.81, while T500 time increased from 2.5 to 6.3 s and V-funnel time from 7.5 to 11.4 s. Density increased from 2364 to 2422 kg/m³. Water absorption decreased from 1.73% to 1.22%; 28-day porosity decreased from 4.44% to 2.94%; 28-day penetration depth decreased from 28 to 12 mm; and 7-day shrinkage strain decreased from 285 to 200 microstrain. On the overall balance adopted in the thesis, the 1.5% hybrid-fiber mix provided the optimum combination of self-compacting behavior and durability-related performance.

Keywords: Self-Compacting Concrete; Hybrid Fiber Reinforcement; Steel Fiber; Polypropylene Fiber; Workability; Porosity; Permeability; Drying Shrinkage.

1. INTRODUCTION

Self-Compacting Concrete (SCC) is designed to flow and compact under its own weight without external vibration. Its filling ability and passing ability make it suitable for congested reinforcement and complex formwork, while reduced dependence on vibration can improve placement quality and reduce site noise and labor requirements. EFNARC guidance provides the principal performance framework used for proportioning and assessing SCC [23].

Despite these advantages, SCC may remain vulnerable to low tensile resistance, brittle behavior, shrinkage cracking, internal pore formation, and water penetration. Hybrid reinforcement combines fibers with complementary functions. Steel fibers bridge larger cracks and improve toughness, whereas polypropylene fibers control microcracks and plastic-shrinkage effects. Previous studies reported that hybrid fibers can reduce slump flow and increase flow time while improving crack resistance, compactness, and durability-related behavior [1-4, 9, 12, 15-18].

The thesis identified a need for focused evaluation of physical and durability properties when steel and polypropylene fibers are used together in SCC. Accordingly, the objectives were to evaluate fresh properties, develop M40 SCC mixes with 1%, 1.25%, 1.5%, and 1.75% hybrid fibers, and determine an optimum dosage based on the combined fresh and hardened response.

2. RELATED WORK

Research summarized in the thesis consistently indicates a workability-durability trade-off. Liu et al. found that steel-polypropylene hybrid fibers reduced slump flow and increased V-funnel time while lowering water absorption, porosity, and permeability [2]. Hussain et al. similarly reported reduced flowability but improved crack control and structural integrity [3]. Karatas and Gunes observed enhanced cohesiveness and moisture resistance, with polypropylene fibers limiting shrinkage cracks and steel fibers increasing toughness [4].

Studies of structural and material behavior also support the complementary action of the two fiber types. Hybrid fiber SCC deep beams showed improved crack resistance and delayed failure [7], while hybrid SCC containing crushed sand exhibited improved compactness and reduced permeability [8]. Reviews and broader experimental investigations emphasize that an appropriate dosage is essential because increasing fiber content can strengthen crack control but may impair filling and passing ability [16-18]. The present study therefore evaluates both fresh-state indicators and durability-related physical properties across four fiber dosages.

3. MATERIALS AND METHODS

3.1 Experimental program

A control SCC mix and four HFRSCC mixes were prepared for M40 grade concrete. The total hybrid-fiber contents were 1%, 1.25%, 1.5%, and 1.75%, with steel and polypropylene fibers used as the hybrid system. The methodology followed the sequence shown in Figure 1.

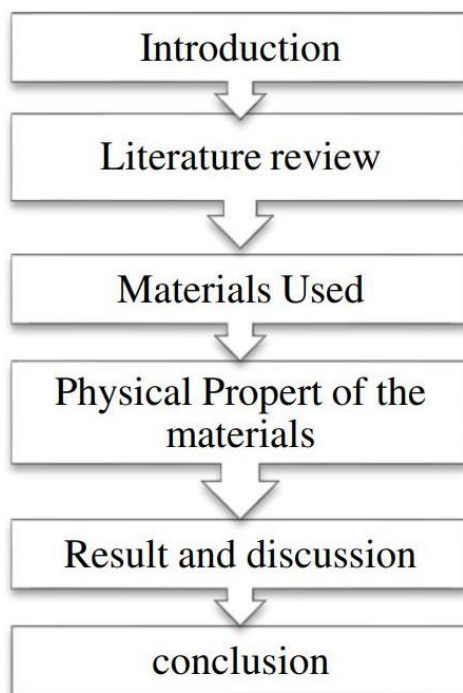


Figure 1. Methodology workflow reported in the thesis.

3.2 Constituent materials

The binder system comprised OPC 53 grade cement, Class F fly ash, and ground-granulated blast-furnace slag (GGBS). River sand was used as fine aggregate and 10 mm aggregate as coarse aggregate. Clean potable water, a polycarboxylate-ether superplasticizer, and a viscosity-modifying admixture were used to obtain self-compacting behavior. Steel fibers were reported as 10 mm discrete fibers, while polypropylene fibers were reported in the 6-12 mm length range. The thesis used a 60:40 steel-to-polypropylene proportion in the mix table.

Table 1. Principal material properties reported in the thesis.

Material/property	Reported value	Article use
OPC normal consistency	30%	Binder characterization
OPC initial/final setting time	45/320 min	Binder characterization
OPC specific gravity	3.15	Mix design
Fine aggregate specific gravity	2.64	Mix design
Fine aggregate fineness modulus	2.83	Aggregate grading
Coarse aggregate specific gravity	2.65	Mix design
Coarse aggregate water absorption	0.14%	Aggregate characterization
Coarse aggregate flakiness/elongation	5.26%/14.26%	Aggregate characterization

3.3 Mix design and proportions

The SCC mix was proportioned with reference to IS 10262:2019 and EFNARC guidance [21,23]. The reported target mean strength was 48.25 MPa. After superplasticizer reduction, the water content was 180 kg/m³. Total powder content was 540 kg/m³, giving a water-to-powder ratio of 0.34. Cementitious replacement was reported as 35%, divided into 141.75 kg/m³ fly ash and 47.25 kg/m³ GGBS.

Table 2. Reported mix quantities for 1 m³ of SCC.

Material	Quantity
Cement	351 kg/m ³
Water	180 kg/m ³
Fine aggregate	851 kg/m ³
Coarse aggregate	810 kg/m ³
Fly ash	141.75 kg/m ³
GGBS	47.25 kg/m ³
Superplasticizer	5.4 kg/m ³
Viscosity-modifying admixture	2.7 kg/m ³
Steel fiber (60%)	6.48 kg/m ³
Polypropylene fiber (40%)	4.32 kg/m ³

Note: Fiber quantities are reproduced as reported in the thesis mix table; separate mass quantities for each variable total fiber percentage were not tabulated.

3.4 Casting, curing, and tests

Constituents were dry mixed before water and admixtures were introduced. Concrete was placed in standard molds without external vibration, stored for approximately 24 h, demolded, and water cured. The thesis states that one specimen per mix proportion was prepared for each hardened-property test. Fresh SCC was assessed using slump flow and T500, V-funnel, and L-box tests. Hardened testing covered density, water absorption, porosity, permeability, and drying shrinkage.



Slump-flow test



V-funnel test



L-box test



Density test



Shrinkage test

Figure 2. Test setups and specimens reproduced from the thesis.

The principal calculations were: Density = mass/volume; Water absorption (%) = $[(W_{sat} - W_{dry})/W_{dry}] \times 100$; Porosity (%) = $[(W_{sat} - W_{dry})/(\rho_w V)] \times 100$; and Shrinkage strain = $[(L_0 - L_t)/L] \times 10^6$.

4. RESULTS AND DISCUSSION

4.1 Fresh properties

Table 3. Slump flow, T500, and V-funnel results.

Fiber content	Slump flow (mm)	T500 (s)	V-funnel (s)
0%	780	2.5	7.5
1%	740	3.5	8.3
1.25%	710	4.5	9.2
1.5%	670	5.5	10.2
1.75%	640	6.3	11.4

Table 4. L-box passing-ability results.

Fiber content	H1 (mm)	H2 (mm)	H2/H1
0%	200	195	0.97
1%	200	188	0.94
1.25%	200	180	0.90
1.5%	200	170	0.85
1.75%	200	162	0.81

Workability decreased progressively as hybrid-fiber content increased. Slump flow fell by 140 mm between the control and 1.75% mix, while T500 and V-funnel times increased. The L-box blocking ratio decreased from 0.97 to 0.81, indicating reduced passing ability as fiber-particle interaction and internal resistance increased. The thesis nevertheless reports that the mixes remained within the intended SCC performance range and identifies 1.5% as the best overall balance.

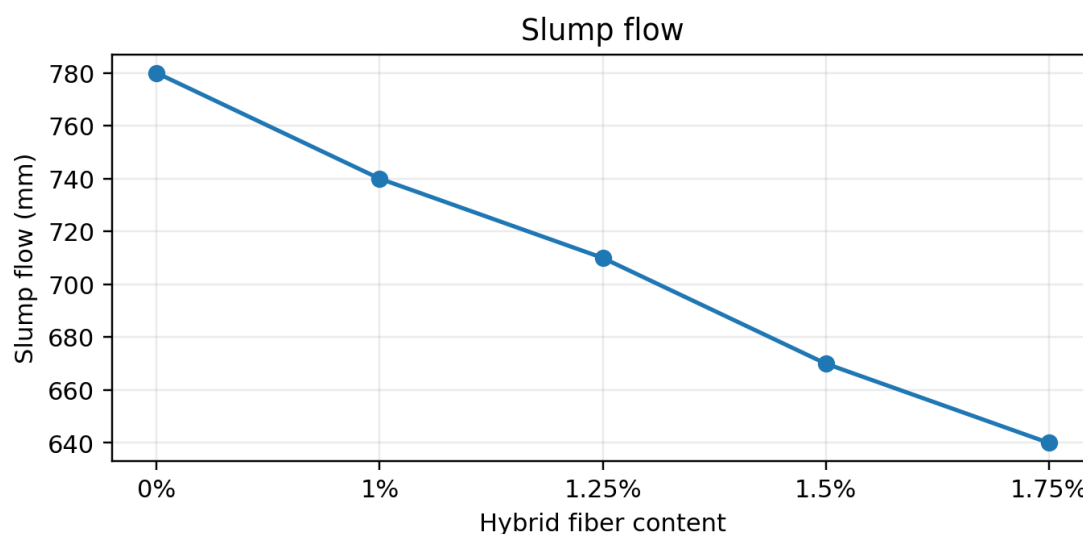


Figure 3. Variation of slump flow with hybrid-fiber content.

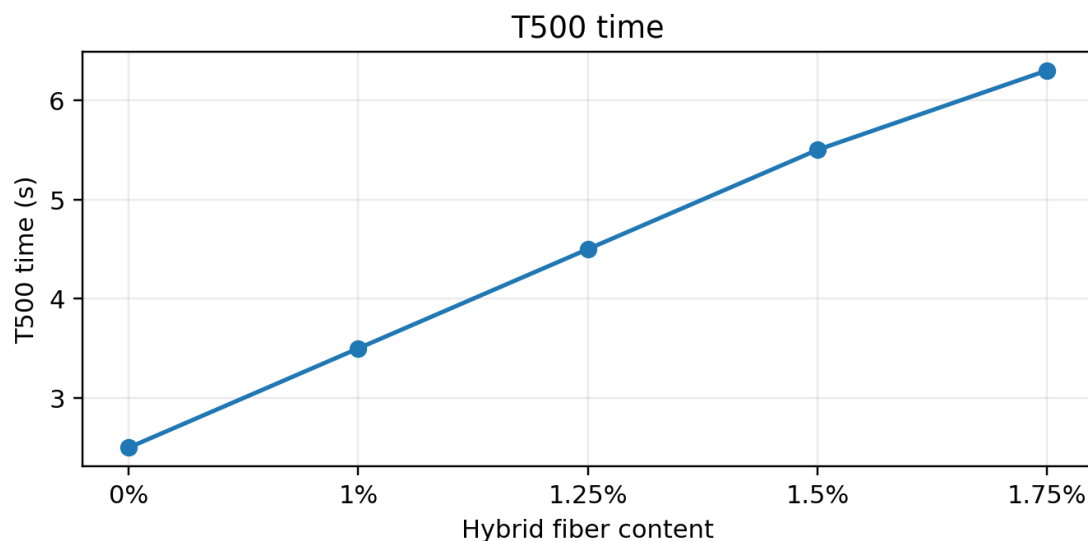


Figure 4. Variation of T500 time with hybrid-fiber content.

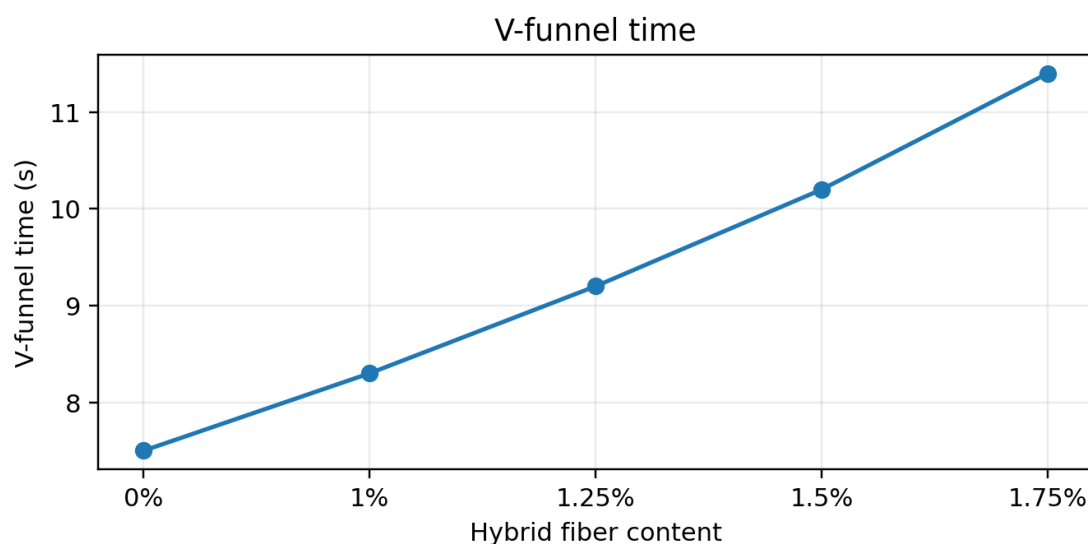


Figure 5. Variation of V-funnel time with hybrid-fiber content.

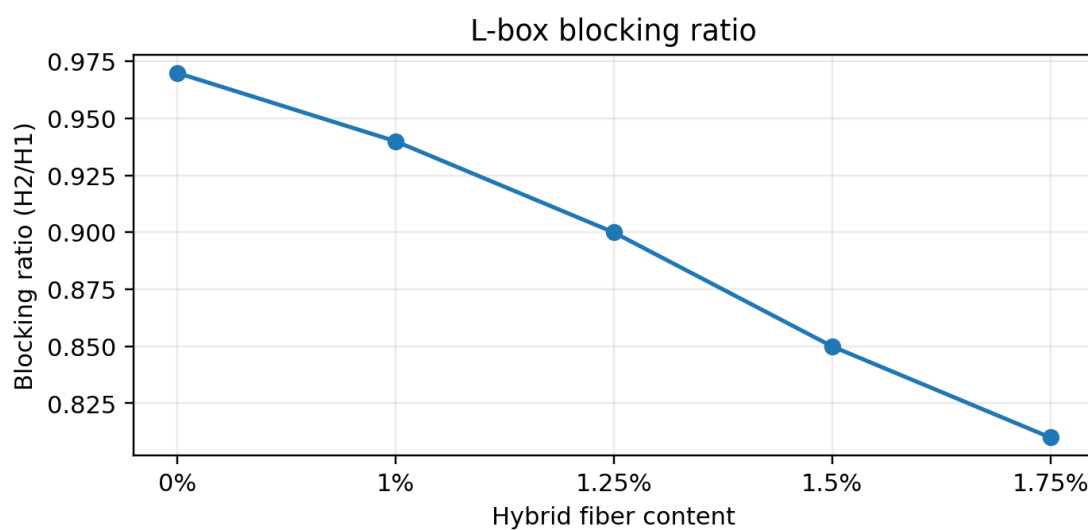


Figure 6. Variation of L-box blocking ratio with hybrid-fiber content.

4.2 Density and water absorption

Table 5. Density and water-absorption results.

Mix	Fiber content	Density at 7 days (kg/m ³)	Water absorption (%)
Normal	0%	2364	1.73
FRC1	1%	2385	1.71
FRC2	1.25%	2398	1.59
FRC3	1.5%	2409	1.47
FRC4	1.75%	2422	1.22

Density increased with fiber content, from 2364 kg/m³ for the control to 2422 kg/m³ at 1.75%, while water absorption declined from 1.73% to 1.22%. The thesis attributes these trends to improved internal bonding, a denser matrix, and fewer connected voids. Although the 1.75% mix produced the highest density and lowest absorption, the 1.5% mix was selected as the balanced optimum when fresh properties were also considered.

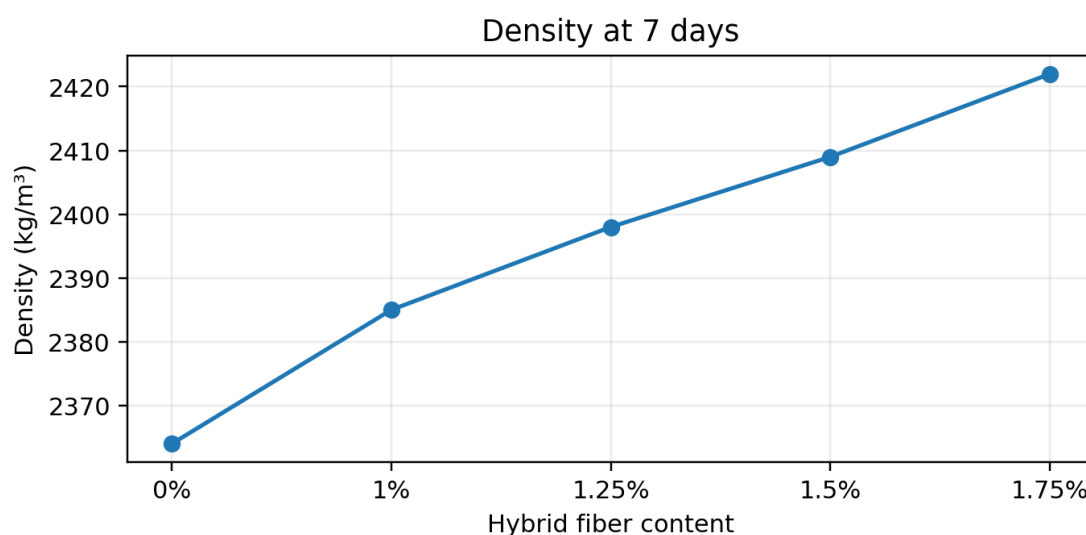


Figure 7. Density at 7 days.

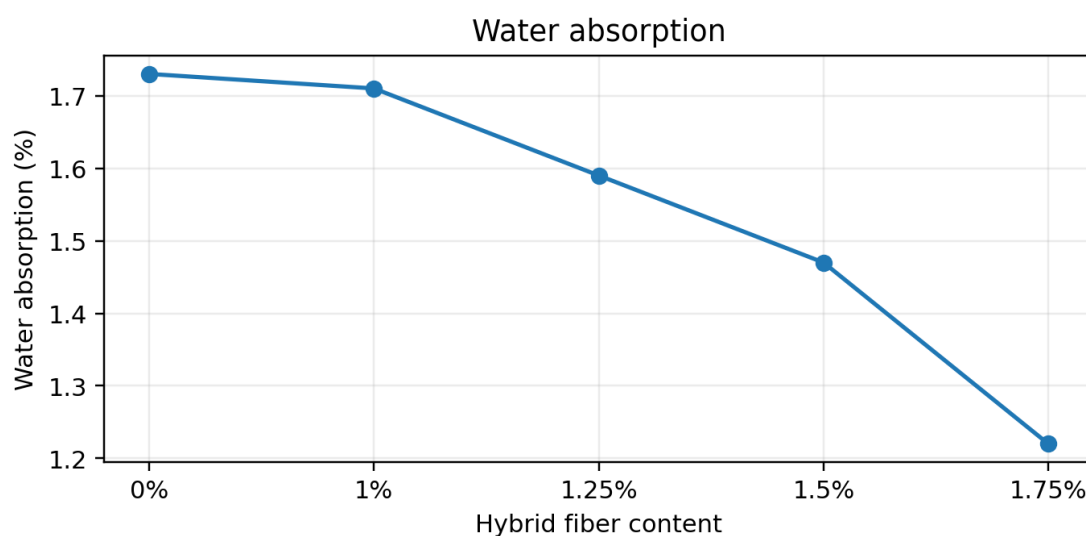


Figure 8. Water absorption.

4.3 Porosity

Table 6. Porosity at 7 and 28 days.

Fiber content	Porosity at 7 days (%)	Porosity at 28 days (%)
0%	5.12	4.44
1%	4.75	4.15
1.25%	4.43	3.86
1.5%	3.96	3.25
1.75%	3.65	2.94

Porosity decreased with both curing time and fiber content. The control decreased from 5.12% at 7 days to 4.44% at 28 days, whereas the 1.75% mix decreased from 3.65% to 2.94%. The thesis relates the reduction over time to continued hydration and the reduction across fiber contents to improved crack control and matrix continuity.

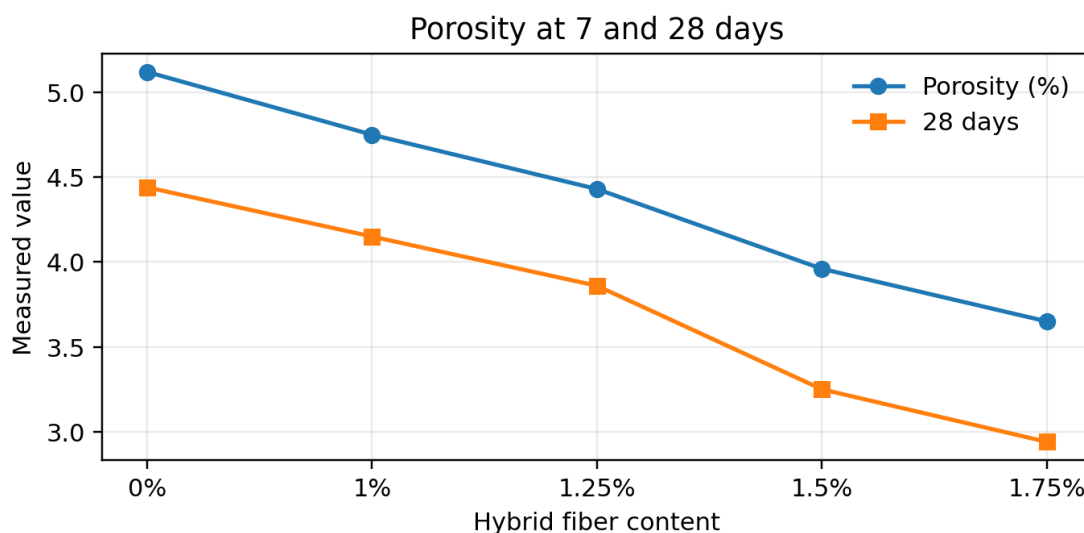


Figure 9. Porosity at 7 and 28 days.

4.4 Permeability

Table 7. Water-penetration depth at 7 and 28 days.

Fiber content	7-day penetration (mm)	28-day penetration (mm)
0%	33	28
1%	30	23
1.25%	23	19
1.5%	21	15
1.75%	19	12

Water-penetration depth decreased at higher fiber contents and at the longer curing period. At 28 days, penetration decreased from 28 mm in the control to 12 mm at 1.75%. The reported behavior is consistent with lower connected porosity and restricted crack-assisted water movement.

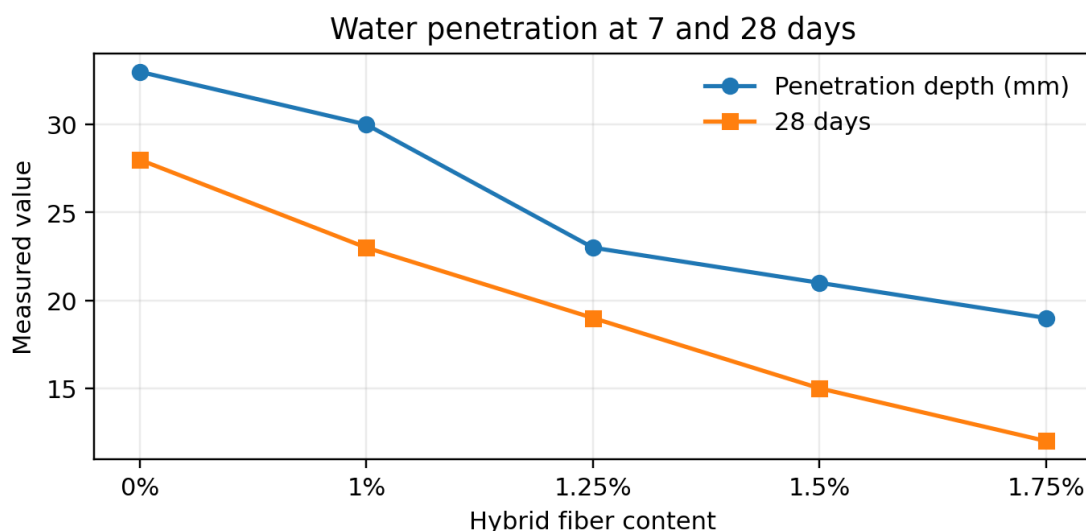


Figure 10. Water-penetration depth at 7 and 28 days.

4.5 Drying shrinkage

Table 8. Drying-shrinkage results at 7 days.

Mix	Fiber content	Initial length (mm)	Final length (mm)	Shrinkage strain (μ strain)
Normal	0%	285	284.91	285
Fr1	1%	285	284.92	260
Fr2	1.25%	285	284.93	240
Fr3	1.5%	285	284.93	220
Fr4	1.75%	285	284.94	200

Drying-shrinkage strain decreased from 285 microstrain for the control to 200 microstrain for the 1.75% mix. The thesis attributes the reduction to crack-bridging by steel fibers and control of microcracks and moisture-loss effects by polypropylene fibers.

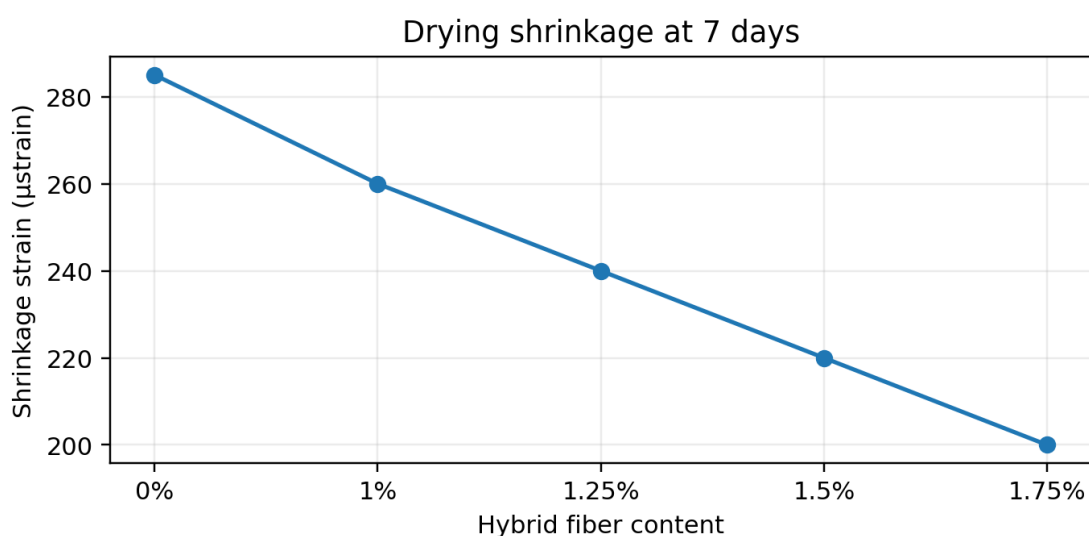


Figure 11. Drying-shrinkage strain at 7 days.

4.6 Overall performance

The results establish a consistent trade-off: increasing hybrid-fiber content reduced flow and passing ability but improved density, absorption, porosity, permeability, and shrinkage indicators. The maximum dosage produced the strongest individual durability indicators, while the thesis selected 1.5% as the optimum because it retained a more favorable balance between self-compacting performance and hardened-state improvement. Because the thesis reports one specimen per mix for each hardened test and no inferential statistical analysis, the findings should be interpreted as the reported experimental trends for the tested program.

5. CONCLUSION

- Hybrid steel and polypropylene fibers progressively reduced SCC workability: slump flow and L-box ratio decreased, while T500 and V-funnel times increased.
- The hybrid system improved durability-related physical properties. Density rose with fiber content, while water absorption, porosity, penetration depth, and drying shrinkage decreased.
- The 1.75% mix gave the highest density and the lowest measured absorption, porosity, permeability, and shrinkage values.
- Considering both fresh and hardened behavior, the thesis identifies the 1.5% hybrid-fiber mix as the optimum balanced dosage.
- The results support use of appropriately proportioned hybrid fibers where SCC flowability must be maintained together with improved crack control and moisture resistance.

DECLARATIONS

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SUPPLEMENTARY MATERIAL CHARACTERIZATION

Table A1. Tests on cement.

Sl. no.	Experiment	Result
1	Normal consistency	30%
2	Initial setting time	45 min
3	Final setting time	320 min
4	Specific gravity by Le-Chatelier method	3.15

Table A2. Fine-aggregate sieve analysis.

Sieve size	Weight retained (g)	Cumulative retained (g)	% retained	Cumulative %	% passing
4.75	51.02	51.02	5.102	5.102	94.989
2.36	61.46	112.48	6.146	11.248	88.752
1.18	176.1	288.58	17.61	28.58	71.142
600	189.9	478.49	18.99	47.849	52.151
300	441.31	919.8	44.131	91.849	8.020

Sieve size	Weight retained (g)	Cumulative retained (g)	% retained	Cumulative %	% passing
150	65.4	985.8	6.54	98.52	1.48
Pan	14.78	-	-	-	-

Reported total of cumulative percentage retained = 283.557; fineness modulus = 2.83.

Table A3. Coarse-aggregate properties.

Property	Result
Water absorption	0.14%
Specific gravity	2.65
Flakiness index	5.26%
Elongation index	14.26%

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