PERFORMANCE–MIX CO-OPTIMIZATION IN SELF-COMPACTING FIBER-REINFORCED CONCRETE

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Abstract. This review compiles quantitative evidence on self compacting fiber reinforced concrete, focusing on specification windows and fiber dosage effects. Practice targets are slump flow 650 to 800 millimetres, T500 about 2 to 5 seconds, V funnel about 8 to 14 seconds, L box H2 over H1 not less than 0.80, and J ring step not more than 10 millimetres. Steel fibers enhance tensile and flexural response but narrow the fresh property window, with slump flow decreases of 50 millimetres at 0.25% and 220 millimetres at 0.50%, and V funnel increases of 11%, 38%, 50% and 63% at 0.25, 0.50, 0.75 and 1.00%; compliant mixes show T500 near 2.2 to 3.5 seconds. A compact table links dosage to changes in slump flow, T500, V funnel and passing checks, and a variable response map connects paste content, grading, admixture compatibility and fiber geometry to acceptance indices, supporting mix design and verification under dense reinforcement and long delivery.

Keywords. self compacting concrete; steel fiber; fresh properties; slump flow; V funnel; L box; passing ability; pumpability; mix design

INTRODUCTION

Self compacting fiber reinforced concrete in congested members and long delivery must satisfy passing ability, stability and pumpability, while fibers that improve toughness also raise flow resistance and the risk of blockage or segregation [1]. Practice relies on slump flow with T500, V funnel and J ring or U box to control filling, viscosity and passing, yet many studies list mix tactics without converting these metrics into a site facing acceptance route that links laboratory windows to placement and pumping limits [2]. Here a performance window is defined that ties target ranges for these tests to paste volume, aggregate grading, admixture compatibility and fiber content and geometry, aligning mix adjustments and on site checks to verify passing and stability together with strength, cost and durability under realistic delivery conditions.

LITERATURE REVIEW

Field practice uses a common acceptance set for self compacting fiber reinforced concrete: slump flow with T500 for filling and cohesion, V funnel for stability, J ring or U box for passing, and sieve or visual indices for segregation, with performance governed by paste volume, continuous grading, admixture compatibility and fiber dosage and geometry [3]. These tests act as a window that narrows with reinforcement congestion and pumping length, so mixes require context specific tuning [3]. Fibers improve post cracking response but can reduce filling and passing when volume fraction or aspect ratio exceed workable ranges; guidance pairs a minimum effective fiber content with adjustments to paste, sand ratio and superplasticizer to keep segregation low and V funnel and J ring within limits [4]. Pressure based analyses of

pumped self consolidating concrete show rising apparent viscosity along the line, longer V funnel times and larger J ring differences, so stability and passing windows tighten with pressure and temperature and require tighter targets and small on site checks before full placement [5].

MATERIALS AND METHODS

Searches of Scopus, Web of Science Core Collection and Google Scholar for 2010 to 2025 included peer reviewed articles and standards with numerical results for slump flow, T500, V funnel, L box, J ring and strength, excluded non SCC and no data items, and recorded binder system, water to binder ratio, maximum aggregate size, fiber descriptors, test method and outcomes, with fresh data harmonised to SCC classes SF1 to SF3, VS1 to VS2, VF1 to VF2, PA1 to PA2 and SR1 to SR2. The literature supports a window based approach that ensures compatibility with polycarboxylate superplasticizers, holds water to binder ratio constant with moisture correction, and varies paste volume, sand ratio, upper aggregate size, admixture dosage and fiber geometry [6]. Reported practice follows three steps that tune a baseline mix to meet acceptance limits, select the minimum effective fiber content and aspect ratio while keeping indices within the window, and refine one variable at a time, as summarised in Figure 1 [7].

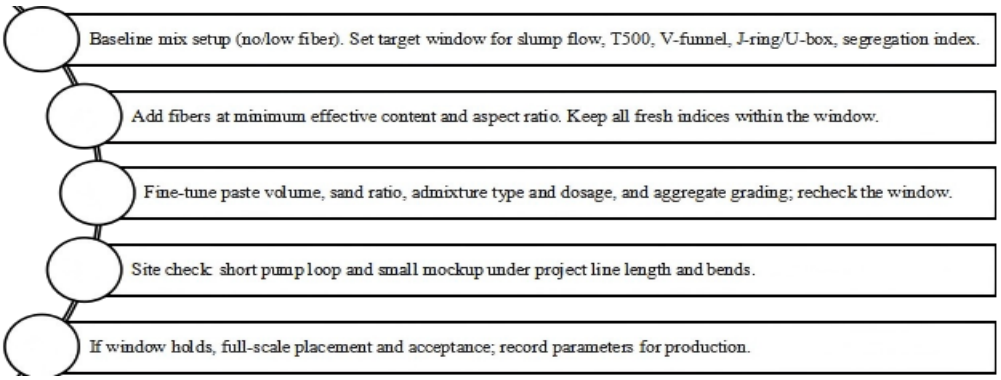

Figure 1. Performance-window–based mix-design co-optimization and site-verification workflow for self-compacting fiber-reinforced concrete (SFRSCC).

RESULTS

According to widely used standards for SCC, slump flow is classified as SF1 to SF3, T500 as VS1 to VS2, V funnel as VF1 to VF2, L box as PA1 to PA2, and sieve segregation as SR1 to SR2. Typical practice targets are slump flow 650 to 800 millimetres, T500 about 2 to 5 seconds, V funnel about 8 to 14 seconds, L box passing ratio H2 over H1 not less than 0.80, and J ring blocking step not more than 10 millimetres; the classification and acceptance windows follow the European Guidelines for SCC and EN 12350 parts 8, 9, 10 and 12 with segregation classes per EN 206, see Table 1 [8–12].

Property and test	Standard	Classification or acceptance window	Typical target for structural practice
Slump flow, diameter in millimetres	EN 12350-8	SF1 550 to 650; SF2 660 to 750; SF3 760 to 850	650 to 800
T500, time in seconds	EN 12350-8	VS1 2 or less; VS2 more than 2	about 2 to 5
V funnel, time in seconds	EN 12350-9	VF1 8 or less; VF2 9 to 25	about 8 to 14
L box, passing ratio H2 over H1	EN 12350-10	acceptance not less than 0.80	not less than 0.80

J ring, blocking step in millimetres	EN 12350-12	commonly used limit not more than 10	not more than 10
Sieve segregation, SR %	European Guidelines and EN 206	SR1 not more than 20; SR2 not more than 15	15 or less for tall vertical elements

Table 1. Standard tests and specification windows for self compacting concrete and SFRSCC [8–12]

Steel fibers reduce slump flow and passing with dosage, while T500 and V funnel times rise; compliant mixes are maintained by increasing paste volume, reducing the maximum aggregate size and adjusting high range water reducers and viscosity modifying admixtures. Quantitatively, V funnel time increases are about 11%, 38%, 50% and 63% at 0.25, 0.50, 0.75 and 1.00% fiber volume, with slump flow losses near 50 mm at 0.25% and 220 mm at 0.50% for hooked end fibers, and compliant T500 about 2.2–3.5 s at slump flow about 600–700 mm. Compressive strength changes little, while splitting tensile and flexural strengths increase, for example flexural from about 6.2 MPa to 7.0 MPa at 1.05% micro steel fibers; details are given in Table 2 [13–15].

Fiber set	Dose (% vol)	Slump flow Δ (mm)	T500 (s)	V-funnel Δ (%)	Passing limits	Mechanical
Hooked end SF[13,14]	0.25 to 1.00	−50 at 0.25; −220 at 0.50	2.2 to 3.5	+11 at 0.25; +38 at 0.50; +50 at 0.75; +63 at 1.00	H2/H1 min 0.80; J-ring max 10 mm	split, flexural +; compressive 0 to −7%
Micro or short SF [15]	0.90 to 1.05	600 to 700	2.2 to 3.5	up with dosage	H2/H1 min 0.80	flexural +10 to +15% (6.2 to 7.0 MPa at 1.05%)
SF in M to H strength SCC [13]	0.50 to 2.00	down with dosage	up with dosage	up with dosage	passing loss in dense cages unless paste, grading adjusted	toughness +; compressive to −7.5%

Note. H2 and H1 are the downstream and upstream heights in the L-box after flow stops; H2/H1 is the L-box passing ratio per EN 12350-10, acceptance not less than 0.80. J-ring step is the height difference measured in the J-ring test per EN 12350-12, acceptance not more than 10 mm. “Dose (% vol)” is fiber volume fraction of concrete. “Δ” means change relative to a SCC reference without fibers. “+” means increase, “–” means decrease. “M to H” means medium to high strength SCC. “SF” means steel fibers. Units: mm millimetres, s seconds, % %.

Table 2. Numeric effects of steel fibers in self compacting concrete

At constant water to binder ratio, more paste lowers yield stress, shortens time to target spread, and gives larger slump flow with smaller T500, while less paste or coarser sand slows flow, lengthens V funnel time, and increases the J ring or U box spread difference; continuous grading stabilises indices and limits segregation, and T500 with V funnel reveal hidden viscosity differences [16].

Higher fiber content or aspect ratio improves residual capacity but raises flow resistance near the paste packing limit, seen as lower spread, longer T500 and V funnel times, and greater passing loss in congested reinforcement; shorter or hybrid fibers reduce these penalties, and superplasticizer recovers spread only within the compatibility range, since overdose causes segregation even at large spread [17]. Under long line pumping, mixes stable in static tests can drift to higher viscosity, indicated by longer V funnel after circulation and a larger J ring difference, with line pressure confirming real rheology change; pressure based interpretation separates cases correctable by modest paste and admixture adjustment from those that require shorter

fibers or lower fiber content [16–18]. Table 3 summarises the variable response map and field cues.

Variable change	Fresh indices (slump flow, T500, V-funnel, J-ring or U-box)	Segregation index	Field cue
Paste volume increased	Larger spread, shorter T500, shorter V funnel time, passing improves	May rise if cohesion is insufficient	Suitable for dense reinforcement; confirm stability
Paste volume decreased or coarser sand	Smaller spread, longer T500, longer V funnel time, passing decreases	Often lower at first, blockage risk increases	Restore with modest paste increase or finer sand
Continuous grading	Indices stable at similar spread, passing improves	Lower and steadier	Prefer for long pumping distance
Superplasticizer dosage increased within compatibility	Spread and passing improve, T500 and V funnel time shorten	Stable when compatibility is good	Stop at the lowest effective dose
Fiber volume or aspect ratio increased	Spread decreases, T500 and V funnel time lengthen, passing decreases	Stable if dispersion is uniform	Limit to the minimum effective content
Shorter or hybrid fibers at the same content	Spread recovers, T500 and V funnel time shorten, passing improves	Little change	Useful compromise for congested reinforcement

Table 3. Variable response map and field cues

CONCLUSION

This review aligns self compacting fiber reinforced concrete with a clear acceptance window and a concise set of adjustment levers. For structural practice, mixes that target slump flow 650 to 800 millimetres, T500 about 2 to 5 seconds, V funnel about 8 to 14 seconds, L box H2 over H1 not less than 0.80 and J ring step not more than 10 millimetres provide a workable basis. Minimum effective fiber volume is preferred, with short or hybrid fibers used where passing is critical. Paste fraction, sand grading and high range water reducer selection are tuned one at a time to keep all fresh indices within the window. The numeric table in the results section gives direct cues for expected changes with dosage, while the variable response map supports diagnosis and correction during proportioning and placement. The approach offers a compact reporting template and facilitates comparison across studies.

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