MIXING SCHEMES FOR BASALT FIBER-REINFORCED CONCRETE: REGULATIONS, RISKS, AND HOMOGENEITY CONTROL

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ABSTRACT

A science-and-engineering rationale is presented for selecting the sequence of component loading during the production of basalt fiber-reinforced concrete (BFRC), with emphasis on the mechanisms of fiber balling formation/prevention and the controllability of fresh-mix rheology. Based on four production-ready mixing schemes described in Chapter 3 of the source document (including the variant with short "wet" fiber dispersion in a dilute PVA solution and early contact with the sand fraction), it is shown that precisely this regimen ensures a stable reduction of the variability of fiber distribution (coefficient of variation V ≈ 7.5–8.0%) while keeping the total cycle time comparable (≈2.5 min), whereas alternative sequences produce a higher spread (V ≈ 9–14%), which naturally manifests as a less stable strength response. These positions are consistent with ACI 544.3R and ACI 304R guidance on the critical role of loading order for FRC and with the European EFNARC recommendations for SCC, where the need to align sequence with target slump-flow, blocking and viscosity indices is set out normatively [1,2,3].

Keywords: *basalt fiber; fiber-reinforced concrete; mixing scheme; loading sequence; homogeneity; coefficient of variation; fiber balling; superplasticizer; polycarboxylate; PVA treatment; turbulent mixer; rotor (pan) mixer; self-compacting concrete; EFNARC; ACI 544.3R; ACI 304R.*

INTRODUCTION

The spatial uniformity of fibers within the cementitious matrix governs the effectiveness of dispersed reinforcement and the reproducibility of BFRC properties; if the loading sequence is violated, the risks of fiber balling increase, pumpability and fiber orientation deteriorate, and the stability of the strength response is impaired. International guidance emphasizes the need to adapt dosing and loading order to FRC (ACI 544.3R) and to general measuring/mixing operations (ACI 304R), while for FR-SCC the EFNARC guideline sets target fresh-state windows (slump-flow, T500, V-funnel, L-box) and explicitly links them to the technological sequence [1,2,3].

MATERIALS AND METHODS

In accordance with [4] of the source material, four mixing schemes were compared for fine-grained and conventional (with coarse aggregate) mixtures, implemented on turbulent and rotor mixers; the coefficient of variation V of local fiber mass fraction in samples taken from different regions of the batch was used as the ultimate homogeneity index, and flexural/compressive strength was also evaluated at normalized ages. The total cycle time was 2.5–3.0 min; the schemes and phase states differed in the order of fiber and liquid/SP introduction (detailed experimental series and V ranges are given in the source document).

RESULTS

Experimentally, the variant with short "wet" dispersion of fibers (brief treatment in a dilute PVA solution) and early mixing with sand provided a stable reduction of V to 7.5–8.0% on both mixer types; alternative sequences yielded V of about 9–14% depending on mixer and grading, which is consistent with the observed increase in flexural strength and moderate increase in compressive strength.

DISCUSSION

The advantage of "wet" dispersion and early fiber–sand contact is due to a decrease in inter-fiber friction and disruption of primary bundles before the main liquid phase is introduced, which prevents coagulation and produces a narrower distribution of local fiber volume fraction; subsequent dosing of water and superplasticizer merely fixes already individualized fibers within a uniformly dispersed system. This mechanism matches the practical recommendations of ACI 304R for preventing balling by managing loading order and mixing, as well as the general provisions of ACI 544.3R on the need to adjust technology to fiber type/dosage; for FR-SCC it is additionally coupled to achieving EFNARC targets (slump-flow, T500, V-funnel, L-box), which depend on sequence and mixer energy [1,2,3].

Table 1

Qualitative appraisal of mixing schemes: mechanism → risk → control

(S — cement; Q — sand/fine aggregate; FT — basalt fiber; SP — superplasticizer; FT — fiber after short PVA treatment)*

Scheme (sequence)	Dominant mechanism of influence	Main technological risks	Recommended control measures	Compatibility with mix type
1: **S+Q → (water+SP) → FT**	FT is added into an already formed mortar	Balling at the inlet, local fiber overdosing,	Dose in small portions, increase turbulence near	Conventional mixes — **conditionally**

	matrix; high shear at dosing point	poorer pumpability	inlet, adjust w/c	**acceptable**; FR-SCC — **undesirable** without extra measures.
2: **Q+S+FT → water → SP**	"Dry" co-mixing of FT with matrix	Fiber damage, dusting, hidden balling	Pre-spread FT in a thin layer, gentle initial regime; early addition of part of liquid	Conventional mixes — **acceptable**; FR-SCC — **limited**.
3: *Q+FT → S → (water+SP)**	"Wet" FT dispersion and early fiber–sand contact	Requires a separate FT* preparation step	Short PVA treatment, control time/speed; then dose water+SP	Conventional and FR-SCC — **preferred**; delivers minimal *V*.
4: **(FT+water+SP) → S+Q → add suspension**	FT introduced as a suspension	Unstable viscosity, risk of segregation if rheology mismatched	Match rheology per EFNARC (slump-flow, *V*-funnel); staged addition	FR-SCC — **feasible** with strict control; conventional — **limited**.

Note. This table is qualitative and fundamentally differs from earlier numeric layouts that listed stage times and V values; the emphasis here is on mechanisms and risk management [4].

Table 2

Fresh-concrete control tests and normative references

Test / indicator	**Standard reference**	**Purpose**	**Typical target range***
Cone slump (non-SCC)	ASTM **C143/C143M**	Mobility assessment for conventional mixes	Set by plant QC for the task; procedure per the standard.
Batch homogeneity (general)	ASTM **C94/C94M**	Uniformity and time/energy of mixing; ready-mixed requirements	Requirements for time/uniformity per standard/contract.
SCC: slump-flow and *T*500	EFNARC (2005)	Mobility and viscosity class	SF1: 550–650 mm, SF2: 660–750 mm, SF3: 760–850 mm; *T*500 typically 2–5 s.
SCC: *V*-funnel	EFNARC (2005)	Viscosity/stability	6–12 s (≥12 s

			indicates higher viscosity).
SCC: *L*-box (blocking ratio)	EFNARC (2005)	Tendency to reinforcement blocking	Ratio 0.8–1.0 acceptable.

* Concrete tolerances are tuned to the recipe and site conditions; for FR-SCC the EFNARC ranges serve as a starting point and are then refined by plant trials.

CONCLUSION

The established regimen that provides short "wet" dispersion of basalt fibers and their early association with the sand fraction, followed by cement and the liquid phase with superplasticizer, ensures a consistently low variability of fiber distribution (V about 7.5–8.0%) without extending the process duration and leads to a reproducible increase in flexural strength, whereas alternative sequences, although within the permissible normative range, show a higher V spread and a less stable strength response; in practice this means fixing the specified scheme in the technological card, aligning mixing regimes with EFNARC fresh-concrete targets for FR-SCC, and applying standard control procedures (ASTM C143/C94) to document homogeneity and mobility [2,5,6].

REFERENCES

1. ACI Committee 544. ACI 544.3R-08: Guide for Specifying, Proportioning, and Production of Fiber-Reinforced Concrete. American Concrete Institute, 2008.
2. ACI Committee 304. ACI 304R-00: Guide for Measuring, Mixing, Transporting, and Placing Concrete. American Concrete Institute, 2000.
3. EFNARC. European Guidelines for Self-Compacting Concrete. May 2005.
4. Obidjonov J.T. Properties of materials used for dispersion-reinforced fiber-reinforced concrete // Web of Scientist: International Scientific Research Journal (WoS), 2022, Vol. 3, pp. 660–666.
5. ASTM International. ASTM C94/C94M – Standard Specification for Ready-Mixed Concrete.
6. ASTM International. ASTM C143/C143M – Standard Test Method for Slump of Hydraulic-Cement Concrete.
7. RILEM TC 162-TDF. Test and Design Methods for Steel Fibre Reinforced Concrete. Materials and Structures (recommendations for FRC testing and design