Mechanical Performance of Concrete Reinforced with Discrete Steel and AR-Glass Fibres: A Comparative Study at 0.5% and 1.5% Dosage in M30 and M40 Grades

Mr. Meet Shet, Ms. Alfiya Sayyed, Dr. Sandeep Ranshur

Department of Civil Engineering

SVKM's Shri Bhagubhai Mafatlal Polytechnic & College of Engineering, Vile Parle, Mumbai

Abstract

The goal of this study is to compare the performance of concrete reinforced with two types of discrete synthetic fibres — steel fibre and alkali-resistant (AR) glass fibre — at two dosages (0.5% and 1.5%) and two concrete grades (M30 and M40). The study examines how these fibres affected cube compressive strength, split tensile strength, beam flexural strength, and thin-panel flexural strength.

Method Summary

Four series of fibre-reinforced concrete were made for each type of fibre. The concrete was tested for strength at 7 and 28 days. Increasing the fibre dosage from 0.5% to 1.5% made the concrete stronger in nearly every test, with one exception (steel fibre split tensile strength at M30, which decreased slightly). Steel fibre was better than AR-glass fibre in every test except one.

Key Finding

The main finding of this study is that steel fibre at 1.5% dosage in M40 grade concrete is the strongest configuration tested. AR-glass fibre also got stronger with increased dosage, but not as strong as steel fibre. Steel fibre at 1.5% dosage in M40 grade concrete is the combination for making the strongest concrete in this study. AR-glass fibre is also a good option — it works better when it is not used in mesh form.

Additional detail from the source document: at M30, 0.5% dosage, steel and AR-glass fibre cube compressive strength were statistically indistinguishable (33.86 MPa vs. 33.90 MPa, $p = 0.99$). AR-glass fibre at 0.5% dosage in M30 grade concrete (Series GF1) was the weakest series overall in three of the four test types.

Conclusion (Abstract)

Steel fibre at 1.5% dosage in M40 grade concrete is the strongest configuration identified in this study across all four test types. AR-glass fibre shows a broadly positive dosage response similar to steel fibre in this discrete-fibre format, in contrast to the dosage-sensitive decline reported for AR-glass mesh (a continuous, mould-placed reinforcement) in comparable studies, suggesting that the dosage response of AR-glass reinforcement is influenced by reinforcement geometry (discrete fibre vs. continuous mesh) rather than being an intrinsic property of the glass material itself.

Keywords: Steel Fibre Reinforced Concrete, AR-Glass Fibre Reinforced Concrete, Fibre Dosage, Compressive Strength, Flexural Strength, Split Tensile Strength

1. Introduction

Fibre reinforcement is used to make concrete stronger. This differs from mesh reinforcement, which is a continuous sheet of material placed into the concrete. Discrete fibres are instead added to the mix and dispersed randomly throughout it, which helps control cracking in the concrete.

This study examines two types of discrete fibre reinforcement — steel fibre and AR-glass fibre — and how they affect the strength of concrete at different dosages and grades.

This work forms part of a broader experimental programme investigating hybrid mesh- and fibre-reinforced concrete systems; the present paper is scoped specifically to the individual steel fibre and AR-glass fibre series, independent of the mesh, polypropylene, and hybrid mesh-fibre combinations also under investigation in that wider programme.

1.1 Research Gap

Most studies on steel and glass fibre reinforced concrete have looked at each fibre type separately, using different mixes and testing methods, which makes it difficult to compare results across studies. This study instead compares the performance of steel and AR-glass fibre using the same methods and materials throughout.

The objectives of this study were to measure the strength of concrete reinforced with each fibre type, to compare the performance of steel and AR-glass fibre directly, and to determine how increasing the fibre dosage affects the strength of the concrete.

Furthermore, the dosage-dependent behaviour of AR-glass reinforcement has not been shown to be consistent across reinforcement geometries: continuous AR-glass mesh has, in related studies, shown a decline in strength with increasing dosage, while the dosage response of discrete AR-glass fibre across multiple specimen geometries has not been directly established in the literature. This paper addresses that gap by investigating both fibre types at two dosages and two grades across four specimen geometries within one controlled experimental programme, in order to isolate the dosage response of each fibre type from confounding variation in matrix or testing conditions.

2. Materials and Methods

Portland cement, river sand, and crushed aggregate were used to make the concrete, along with a superplasticiser to improve the workability of the mix. Two types of fibre reinforcement were tested — steel crimped fibre and AR-glass short fibre — each added to the mix at two dosages, 0.5% and 1.5%. Four types of specimens were cast: strength cubes, split tensile cylinders, flexural strength beams, and flexural thin panels, tested at 7 and 28 days.

2.1 Materials

- Ordinary Portland Cement
- River sand
- Crushed aggregate
- Class F fly ash
- Polycarboxylate ether based superplasticiser

Additional material specifications from the source document: Ordinary Portland Cement was OPC 43 grade (IS 8112:2013); fine aggregate was Zone II river sand (IS 383); coarse aggregate was 10 mm crushed aggregate (IS 383); Class F fly ash (IS 3812 Part 1:2003) was used as a 25% replacement of the cement by weight in all mixes; and the polycarboxylate ether (PCE) based superplasticiser (IS 9103:1999) was used to maintain a target slump of 75 ± 25 mm. Mix proportions were determined in accordance with IS 10262:2019 and IS 456:2000.

The two discrete fibre types were: steel crimped fibre, conforming to IS 16272:2014 and ASTM A820 — drawn steel wire with a crimped/undulated profile for mechanical anchorage, with a typical tensile strength in the range of 1000–1200 MPa for this class of product; and AR-glass short fibre, an alkali-resistant glass fibre suitable for use in a cementitious environment. Both fibres were batched directly into the concrete mix during mixing rather than placed as discrete layers, distinguishing this reinforcement approach from continuous mesh-type reinforcement. Specific fibre geometry (filament diameter, cut length, aspect ratio) and manufacturer-declared tensile properties are recorded in the project's material procurement documentation and are not reproduced in full in this paper; this is noted as a limitation in Section 6.

2.2 Fibre Dosage and Batching

The fibres were added to the mix by weight, using a specific formula to calculate the required quantity for each target dosage.

The formula used: $V_f (\%) = [W / (SG \times 1000)] \times 100$, where W is the batched fibre content in kg/m³ and SG is the specific gravity of the fibre material. The nominal 0.5% and 1.5% dosage designations used as series labels in this paper correspond to the target volumetric fractions calculated by this method for the respective fibre materials; the exact batched weight per m³ for steel and AR-glass fibre is set out in the project's mix design records.

2.3 Mix and Specimen Types

Eight series of fibre-reinforced concrete were cast, covering different combinations of fibre type, grade, and dosage.

Series ID	Reinforcement	Grade	Dosage
SF1	Steel Fibre	M30	0.5%
SF2	Steel Fibre	M30	1.5%
SF3	Steel Fibre	M40	0.5%
SF4	Steel Fibre	M40	1.5%
GF1	AR-Glass Fibre	M30	0.5%
GF2	AR-Glass Fibre	M30	1.5%
GF3	AR-Glass Fibre	M40	0.5%
GF4	AR-Glass Fibre	M40	1.5%

Table 1. Fibre-reinforced mix series and configuration.

Four types of specimens were prepared for each series: compressive strength cubes (150 × 150 × 150 mm), split tensile cylinders (150 mm diameter × 300 mm), flexural strength beams (700 × 150 × 150 mm), and flexural thin panels (300 × 300 × 25 mm). Cube specimens were tested at 7 and 28 days; cylinder, beam, and panel specimens were tested at 28 days.

2.4 Casting and Curing Procedure

The concrete was mixed, the fibres were added, and the mix was cast into moulds. Specimens were left to set for 24 hours, then removed from the moulds and placed in a water tank to cure.

Additional procedural detail from the source document: cement, fly ash, and aggregates were dry-blended, followed by the addition of water and superplasticiser to achieve the design water-binder ratio. The pre-weighed fibre dosage was then added gradually to the wet mix under continuous mixing to promote uniform dispersion and minimise fibre balling, until a homogeneous fibre-reinforced concrete was obtained. The fresh concrete was cast into cleaned, lightly oiled moulds in layers and consolidated to minimise entrapped air, and the top surface was screeded. Specimens remained undisturbed in the moulds for approximately 24 hours before demoulding, after which they were fully immersed in a curing water tank at room temperature until the testing age, in accordance with IS 456:2000. Specimens were removed from the curing tank shortly before testing and tested in the saturated surface-dry condition.

2.5 Test Methods

Specimens were tested for compressive strength, split tensile strength, beam flexural strength, and thin-panel flexural strength. Compressive strength was determined following IS 516:1959, which specifies the method for testing concrete strength. The beams used for the flexural test were 700 × 150 × 150 mm, placed on two roller supports 600 mm apart, and loaded at two points each 200 mm from a support. Panel flexural strength was determined using a similar method, with panels supported at two points and loaded at the midpoint. Results of all tests are given in Section 3.

Additional test method detail from the source document: the beam effective span of 600 mm is four times the specimen depth, and loading followed the third-point (four-point) configuration specified in IS 516:1959. The panel flexural test used the same two-point, mid-span-symmetric loading configuration, scaled proportionally to the panel dimensions, and was likewise simply supported. Cube compressive strength was tested on three replicate specimens per series at each of 7 and 28 days; split tensile, beam flexural, and panel flexural strength are reported at 28 days as single representative values per series in the dataset available for this paper.

3. Results

3.1 Testing Programme

Eight series of fibre-reinforced concrete were tested — four using steel fibre and four using AR-glass fibre — across two concrete grades (M30, M40) and two fibre dosages (0.5%, 1.5%). Cube compressive strength was measured at 7 and 28 days; split tensile, beam flexural, and panel flexural strength were measured at 28 days.

3.2 Compressive Strength

Table 2 gives the mean 7-day and 28-day cube compressive strength for all eight series. As expected, the M40 series had higher 28-day strength than the M30 series. At M30 and 0.5% dosage, steel fibre and AR-glass fibre had the same 28-day strength; at every other grade/dosage combination, steel fibre outperformed AR-glass fibre.

Additional detail from the source document: 28-day strength ranged from 33.9–40.5 MPa for the M30 series and 38.2–49.8 MPa for the M40 series, with the largest steel-vs-glass gap at M40, 1.5% dosage (49.78 MPa vs. 43.69 MPa).

Series	Reinforcement	Grade	Dosage	7-Day (MPa)	28-Day (MPa)
SF1	Steel Fibre	M30	0.5%	22.35	33.86
SF2	Steel Fibre	M30	1.5%	26.62	40.54
SF3	Steel Fibre	M40	0.5%	29.03	44.08
SF4	Steel Fibre	M40	1.5%	32.96	49.78
GF1	AR-Glass Fibre	M30	0.5%	22.20	33.90
GF2	AR-Glass Fibre	M30	1.5%	22.47	34.16
GF3	AR-Glass Fibre	M40	0.5%	25.09	38.24
GF4	AR-Glass Fibre	M40	1.5%	28.79	43.69

Table 2. Mean cube compressive strength, all eight series.

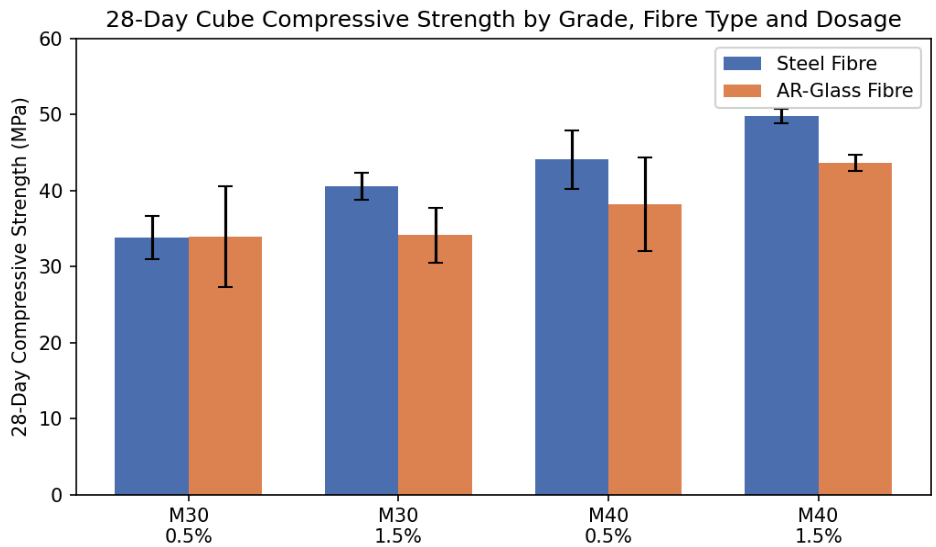

Figure 1. 28-day cube compressive strength by grade, fibre type and dosage. Error bars represent ±1 standard deviation (n=3).

3.3 Split Tensile Strength

Table 3 gives the 28-day split tensile strength for all eight series. Steel fibre outperformed AR-glass fibre at every grade and dosage combination, with the difference ranging from 3% to 43%.

One point flagged directly in the source document: steel fibre split tensile strength at 0.5% dosage is higher at M30 (4.78 MPa) than at M40 (4.60 MPa) — the only instance in the entire dataset where the M30 series outperforms the corresponding M40 series in any test type. This reversal is discussed further in Section 4.4. Split tensile strength is reported as a single representative value per series; replicate data was not available for this test type (Section 6), so it cannot be determined whether this reflects genuine behaviour or specimen-level variability.

Series	Reinforcement	Grade	Dosage	Split Tensile 28-Day (MPa)
SF1	Steel Fibre	M30	0.5%	4.78
SF2	Steel Fibre	M30	1.5%	4.63
SF3	Steel Fibre	M40	0.5%	4.60
SF4	Steel Fibre	M40	1.5%	5.35
GF1	AR-Glass Fibre	M30	0.5%	3.34
GF2	AR-Glass Fibre	M30	1.5%	4.49
GF3	AR-Glass Fibre	M40	0.5%	3.78

Series	Reinforcement	Grade	Dosage	Split Tensile 28-Day (MPa)
GF4	AR-Glass Fibre	M40	1.5%	4.76

Table 3. Split tensile strength, all eight series, 28-day.

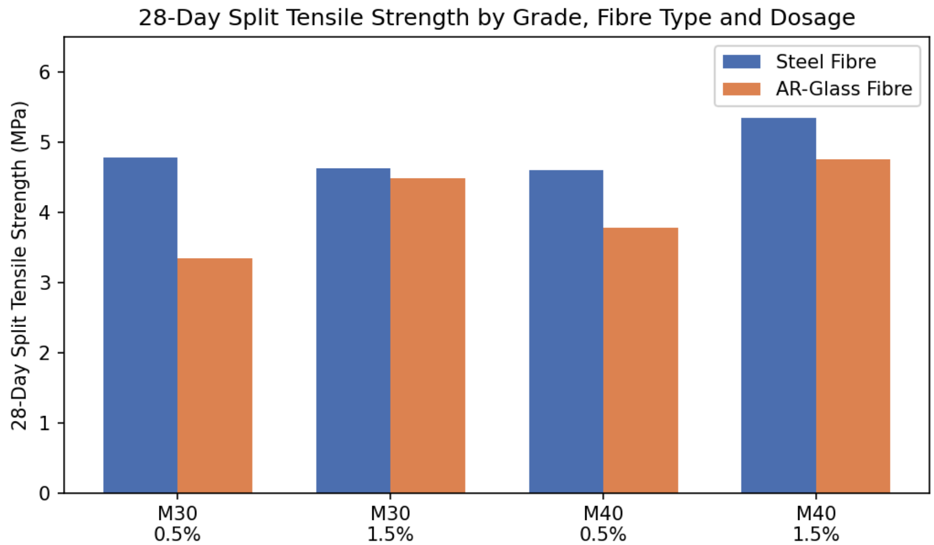

Figure 2. 28-day split tensile strength by grade, fibre type and dosage. Single reported value per series; no replicate data available for error bars (see Section 6).

3.4 Flexural Strength – Beam

Table 4 gives the 28-day beam flexural strength for all eight series. Steel fibre series had higher flexural strength than AR-glass fibre series, with the difference ranging from 16.9% to 46.2%.

Series	Reinforcement	Grade	Dosage	Beam Flexural 28-Day (MPa)
SF1	Steel Fibre	M30	0.5%	4.08
SF2	Steel Fibre	M30	1.5%	4.43
SF3	Steel Fibre	M40	0.5%	4.65
SF4	Steel Fibre	M40	1.5%	4.95
GF1	AR-Glass Fibre	M30	0.5%	2.84
GF2	AR-Glass Fibre	M30	1.5%	3.79
GF3	AR-Glass Fibre	M40	0.5%	3.18
GF4	AR-Glass Fibre	M40	1.5%	4.06

Table 4. Beam flexural strength, all eight series, 28-day.

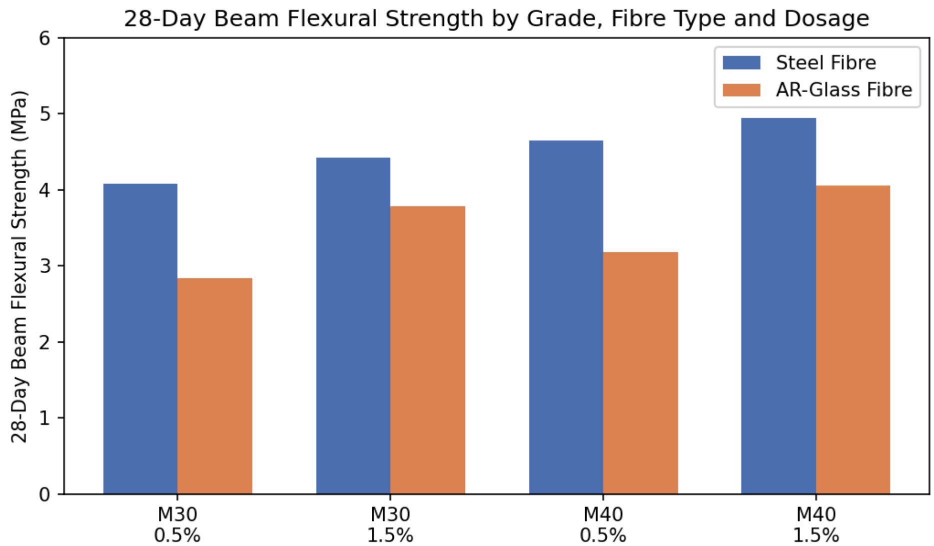

Figure 3. 28-day beam flexural strength by grade, fibre type and dosage. Single reported value per series; no replicate data available for error bars (see Section 6).

During beam testing it was observed that steel fibre beams did not break into two pieces even after failure — the fibres held the two halves of the beam together. AR-glass fibre beams, by contrast, broke into two separate pieces upon failure.

Additional detail from the source document: this qualitative difference in failure behaviour was consistent and independent of grade or dosage. In all four steel fibre series, the beam developed a clear, visible flexural crack at the point of failure but did not separate into two pieces — the fibres bridging the crack continued to hold the two halves of the beam together after the recorded ultimate load was reached. In all four AR-glass fibre series, the beam separated completely into two pieces at failure.

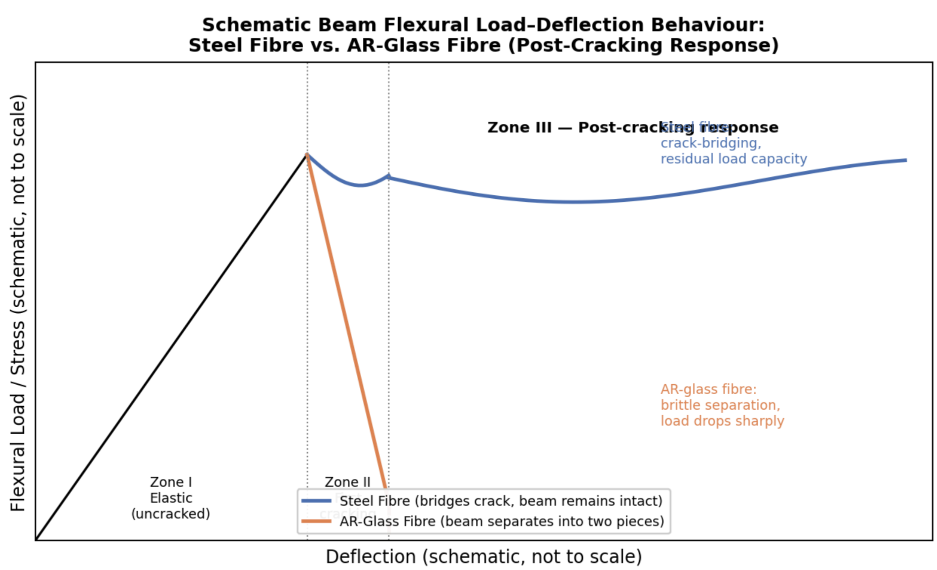

Figure 3b. Schematic illustration of beam flexural post-cracking behaviour for steel fibre versus AR-glass fibre, based on the qualitative failure observations recorded during testing. This is a conceptual diagram, not a measured

load–deflection curve — continuous load–deflection data was not recorded for the beam tests in this study (Section 6).

3.5 Flexural Strength – Thin Panel

Table 5 gives the 28-day panel flexural strength for all eight series. Steel fibre series had higher flexural strength than AR-glass fibre series, with the difference ranging from 27.6% to 50.2%.

Additional detail from the source document: steel fibre at M40, 1.5% dosage (SF4) achieved the highest panel flexural strength recorded in the study, at 4.81 MPa — 67% above the weakest series, AR-glass fibre at M30, 0.5% dosage (GF1, 2.88 MPa).

Series	Reinforcement	Grade	Dosage	Panel Flexural 28-Day (MPa)
SF1	Steel Fibre	M30	0.5%	4.11
SF2	Steel Fibre	M30	1.5%	4.39
SF3	Steel Fibre	M40	0.5%	4.70
SF4	Steel Fibre	M40	1.5%	4.81
GF1	AR-Glass Fibre	M30	0.5%	2.88
GF2	AR-Glass Fibre	M30	1.5%	3.44
GF3	AR-Glass Fibre	M40	0.5%	3.13
GF4	AR-Glass Fibre	M40	1.5%	3.66

Table 5. Panel flexural strength, all eight series, 28-day.

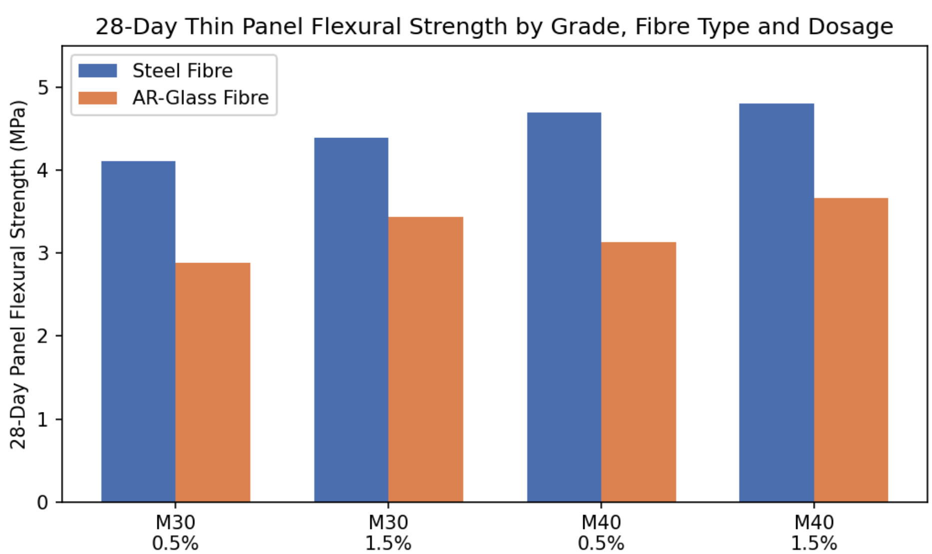

Figure 4. 28-day panel flexural strength by grade, fibre type and dosage. Single reported value per series; no replicate data available for error bars (see Section 6).

3.6 Consolidated Summary

Table 6 consolidates the results of all tests. The steel fibre series performed better than the AR-glass fibre series in nearly every test — the sole exception being cube compressive strength at M30, 0.5% dosage, where AR-glass fibre (GF1, 33.90 MPa) is marginally, and not statistically significantly, ahead of steel fibre (SF1, 33.86 MPa; see Section 3.8).

Series	Reinforcement (Dosage)	Grade	Cube (MPa)	Split Tensile (MPa)	Beam Flexural (MPa)	Panel Flexural (MPa)
SF1	Steel Fibre (0.5%)	M30	33.86	4.78	4.08	4.11
SF2	Steel Fibre (1.5%)	M30	40.54	4.63	4.43	4.39
SF3	Steel Fibre (0.5%)	M40	44.08	4.60	4.65	4.70
SF4	Steel Fibre (1.5%)	M40	49.78	5.35	4.95	4.81
GF1	AR-Glass Fibre (0.5%)	M30	33.90	3.34	2.84	2.88
GF2	AR-Glass Fibre (1.5%)	M30	34.16	4.49	3.79	3.44
GF3	AR-Glass Fibre (0.5%)	M40	38.24	3.78	3.18	3.13
GF4	AR-Glass Fibre (1.5%)	M40	43.69	4.76	4.06	3.66

Table 6. Summary of 28-day strength results, all four test types.

3.7 Percentage Advantage of Steel Fibre over AR-Glass Fibre

Table 7 gives the percentage strength advantage of steel fibre over AR-glass fibre at matched grade and dosage, based on 28-day cube compressive strength. The near-zero, slightly negative gap at M30, 0.5% dosage is attributed primarily to scatter in the AR-glass fibre replicate readings at that condition, discussed further in Section 4.1. (The source data for this table covers the cube compressive comparison; corresponding percentage figures for split tensile, beam flexural, and panel flexural strength were not provided.)

Grade / Dosage	Cube Compressive Advantage (%)
M30, 0.5% dosage	−0.12%
M30, 1.5% dosage	+18.68%
M40, 0.5% dosage	+15.27%
M40, 1.5% dosage	+13.94%

Full breakdown from the source document, across all four test types: at M30, 0.5% dosage, steel fibre's advantage was −0.12% (cube), +43.11% (split tensile), +43.66% (beam flexural), +42.71% (panel flexural). At M30, 1.5% dosage: +18.68% (cube), +3.12% (split tensile), +16.89% (beam flexural), +27.62% (panel flexural). At M40, 0.5% dosage: +15.27% (cube), +21.69% (split tensile), +46.23% (beam flexural), +50.16% (panel flexural). At M40, 1.5% dosage: +13.94% (cube), +12.39% (split tensile), +21.92% (beam flexural), +31.42% (panel flexural). No unreinforced control mix data was available for this fibre programme at the time of writing (Section 6); these comparisons are therefore between fibre types only, not against an unreinforced baseline.

Grade / Dosage	Cube (%)	Split Tensile (%)	Beam Flexural (%)	Panel Flexural (%)
M30, 0.5%	-0.12	+43.11	+43.66	+42.71
M30, 1.5%	+18.68	+3.12	+16.89	+27.62
M40, 0.5%	+15.27	+21.69	+46.23	+50.16
M40, 1.5%	+13.94	+12.39	+21.92	+31.42

3.8 Variability and Statistical Testing

Table 8 lists the 7-day and 28-day cube compressive readings used to derive the means reported in Table 2, together with the mean, standard deviation, and coefficient of variation for each series. The steel fibre series show low scatter, indicating consistent results, while the AR-glass fibre series show substantially higher scatter, indicating less consistent results. This pattern is discussed further in Section 4.1 and flagged as a data-quality limitation in Section 6.

Series	Age	Rep. 1 (MPa)	Rep. 2 (MPa)	Rep. 3 (MPa)	Mean (MPa)	SD (MPa)	CoV (%)
SF1 (M30, 0.5%)	7-Day	20.34	24.56	22.14	22.35	2.118	9.48
SF1 (M30, 0.5%)	28-Day	30.98	36.70	33.90	33.86	2.860	8.45

Series	Age	Rep. 1 (MPa)	Rep. 2 (MPa)	Rep. 3 (MPa)	Mean (MPa)	SD (MPa)	CoV (%)
SF2 (M30, 1.5%)	7-Day	25.26	27.26	27.33	26.62	1.175	4.41
SF2 (M30, 1.5%)	28-Day	38.60	40.99	42.04	40.54	1.763	4.35
SF3 (M40, 0.5%)	7-Day	26.46	31.54	29.10	29.03	2.541	8.75
SF3 (M40, 0.5%)	28-Day	40.09	47.66	44.50	44.08	3.802	8.63
SF4 (M40, 1.5%)	7-Day	32.19	33.28	33.40	32.96	0.667	2.02
SF4 (M40, 1.5%)	28-Day	48.78	49.97	50.60	49.78	0.924	1.86
GF1 (M30, 0.5%)	7-Day	19.42	20.16	27.02	22.20	4.191	18.88
GF1 (M30, 0.5%)	28-Day	29.66	30.50	41.55	33.90	6.636	19.58
GF2 (M30, 1.5%)	7-Day	20.14	25.19	22.07	22.47	2.548	11.34
GF2 (M30, 1.5%)	28-Day	30.67	37.90	33.90	34.16	3.622	10.60
GF3 (M40, 0.5%)	7-Day	25.89	28.87	20.52	25.09	4.232	16.86
GF3 (M40, 0.5%)	28-Day	39.50	43.67	31.55	38.24	6.158	16.11
GF4 (M40, 1.5%)	7-Day	28.08	28.99	29.30	28.79	0.634	2.20
GF4 (M40, 1.5%)	28-Day	42.67	43.60	44.80	43.69	1.068	2.44

Table 8. Individual replicate cube compressive readings, mean, standard deviation, and CoV.

Additional detail from the source document: the steel fibre series show consistently low scatter (CoV 1.9–9.5%), while the AR-glass fibre series — particularly GF1 (M30, 0.5%) at 18.9–19.6% CoV and GF3 (M40, 0.5%) at 16.1–16.9% CoV — show substantially higher scatter, well above the 5–10% range typically expected for well-controlled cube testing. In both cases the elevated CoV is driven by a single outlying replicate (GF1: 41.55 MPa at 28 days against 29.66 and 30.50 MPa for the other two; GF3: 31.55 MPa at 28 days against 39.50 and 43.67 MPa for the other two) rather than uniformly high scatter across all three replicates.

Welch's two-sample t-test was applied to the 28-day compressive strength results for every steel-versus-glass comparison and every 0.5%-versus-1.5% dosage comparison at matched grade. Two comparisons reached significance at the $\alpha = 0.05$ level: steel fibre outperforming glass fibre at M40, 1.5% dosage, and increasing steel fibre dosage from 0.5% to 1.5% significantly increasing compressive strength at M30.

Comparison	Mean A (MPa)	Mean B (MPa)	t (Welch)	p-value	Significant (α=0.05)
Steel vs Glass, M30, 0.5%	SF1=33.86	GF1=33.90	−0.01	0.992	No
Steel vs Glass, M30, 1.5%	SF2=40.54	GF2=34.16	2.75	0.074	No
Steel vs Glass, M40, 0.5%	SF3=44.08	GF3=38.24	1.40	0.248	No
Steel vs Glass, M40, 1.5%	SF4=49.78	GF4=43.69	7.47	0.002	Yes
Steel dosage 0.5%→1.5%, M30	SF1=33.86	SF2=40.54	−3.45	0.035	Yes
Steel dosage 0.5%→1.5%, M40	SF3=44.08	SF4=49.78	−2.52	0.115	No
Glass dosage 0.5%→1.5%, M30	GF1=33.90	GF2=34.16	−0.06	0.957	No
Glass dosage 0.5%→1.5%, M40	GF3=38.24	GF4=43.69	−1.51	0.263	No

Table 9. Welch's two-sample t-test results, 28-day compressive strength.

Additional detail from the source document: of the eight comparisons tested, only two reach significance at the $\alpha = 0.05$ level. The remaining six comparisons, while showing the same directional trends discussed in Section 4, do not reach significance at the present replicate count (n=3) — in several cases because of the high scatter in the AR-glass fibre replicates noted above. A larger replicate count would be needed to confirm these trends statistically. Equivalent significance testing could not be performed for split tensile, beam flexural, or panel flexural strength, as only single representative values (not replicate sets) were available for those test types.

4. Discussion

4.1 Effect of Fibre Type

Steel fibre outperformed AR-glass fibre in every test combination and grade/dosage pairing except one (M30, 0.5% dosage cube compressive strength, where the two were effectively equal). The gap between the two fibre types is narrow in cube compressive strength but larger in split tensile, beam flexural, and thin-panel flexural strength.

Additional detail from the source document: the cube compressive gap ranges from −0% to +19% across the four grade/dosage combinations. In split tensile, beam flexural, and thin-panel flexural strength the gap is generally larger and reaches as high as 50%, though not uniformly — split tensile drops to as little as 3% at M30, 1.5% dosage, while beam and panel flexural strength remain substantial (17–46% and 28–50% respectively) across all four grade/dosage combinations. This pattern — a modest reinforcement effect in bulk compression but a generally pronounced effect in tension-dominated and thin-section tests — is consistent with the general mechanism by which fibre reinforcement acts primarily on post-cracking tensile and flexural behaviour rather than on the compressive strength of the surrounding matrix. Steel fibre's higher stiffness, higher tensile strength (typically 1000–1200 MPa for crimped steel fibre), and mechanical (crimped) anchorage profile are the most likely contributors to its consistent advantage over AR-glass fibre in the tension- and flexure-dominated test types. This mechanism is also supported qualitatively by the beam failure behaviour recorded in Section 3.4: crimped steel fibre's mechanical anchorage profile provides continued load transfer across a crack after first cracking, a post-cracking bridging action that a lower-stiffness, non-mechanically-anchored AR-glass fibre is less able to sustain to the point of complete separation.

4.2 Effect of Fibre Dosage

Increasing fibre dosage from 0.5% to 1.5% increased strength in nearly every test configuration for both fibre types, with one exception (steel fibre split tensile strength at M30). This is a different dosage response from what has been reported for AR-glass mesh reinforcement in other studies, where increasing dosage has been associated with reduced strength. The reason proposed for AR-glass mesh's negative dosage response is that mesh apertures block the flow of the mix at higher layer counts — a mechanism that does not apply to a system of discrete, randomly dispersed fibres, since there is no mesh sheet to obstruct the flow of the concrete mix during casting.

Additional detail from the source document: the dosage increase was positive in nearly every configuration, with one specific exception — steel fibre split tensile strength at M30, which showed a small decrease of 3.1% when dosage increased from 0.5% to 1.5%. The largest relative gains from increased dosage belonged to AR-glass fibre in split tensile (+25–34%) and beam flexural strength (+28–33%), exceeding the equivalent steel fibre gains in those same test types — see Figure 5 below.

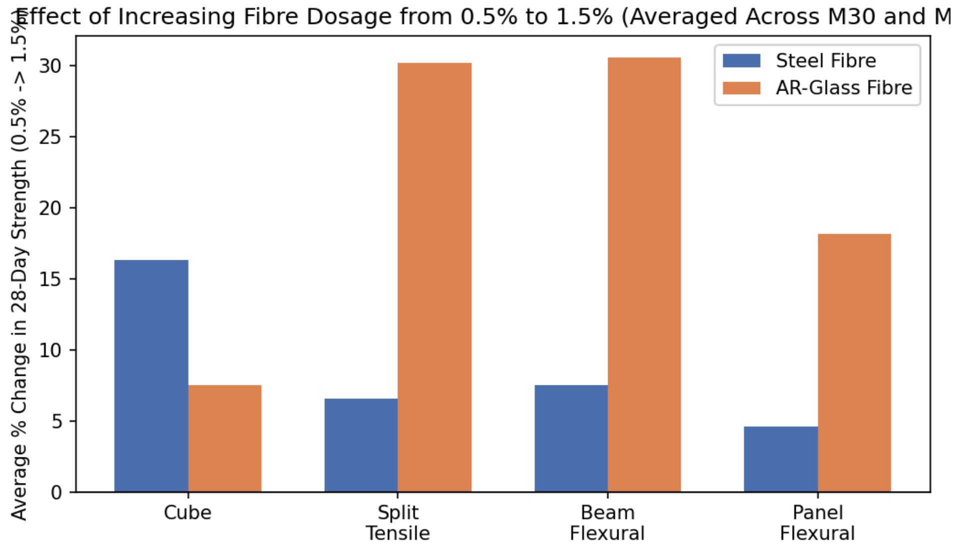

Figure 5. Average percentage change in 28-day strength when fibre dosage is increased from 0.5% to 1.5%, by test type and fibre type (averaged across M30 and M40).

4.3 Best-Performing Configuration

M40 grade concrete with 1.5% steel fibre dosage (Series SF4) had the highest strength value among all series in each of the four test configurations: 49.78 MPa in compression, 5.35 MPa in split tension, 4.95 MPa in beam flexure, and 4.81 MPa in panel flexure.

Looking at the panel results specifically: increasing grade from M30 to M40 at 0.5% steel fibre dosage increased panel flexural strength by 0.59 MPa, while increasing dosage from 0.5% to 1.5% at M30 increased panel flexural strength by 0.28 MPa.

Additional detail from the source document: if these two effects (grade increase, dosage increase) acted independently and additively from the SF1 baseline (4.11 MPa panel flexural), the combined M40/1.5% result would be predicted at 4.98 MPa; the measured SF4 value of 4.81 MPa is 0.17 MPa (3.4%) below this additive prediction — a small negative (sub-additive) interaction rather than a positive one. The same pattern holds in cube compressive strength: the additive prediction from SF1 (33.86 MPa) is 50.76 MPa, against a measured SF4 value of 49.78 MPa (−1.9%). This suggests that, for discrete steel fibre in this dataset, the combined benefit of higher grade and higher dosage shows mild diminishing returns rather than synergy, though the magnitude of this effect is small relative to the standard deviations of the individual series (Table 8) and would need a wider grade/dosage matrix to confirm.

4.4 Effect of Concrete Grade

The M40 series had higher strength values than the M30 series in 15 out of 16 grade comparisons across all four test types and both reinforcement types. The single exception was steel fibre split tensile strength at 0.5% dosage, where the M30 series had a higher strength value than the M40 series.

Additional detail from the source document: the M30 value in this exception was 4.78 MPa (SF1) against 4.60 MPa for M40 (SF3). This is reported as-is rather than smoothed over; since split tensile strength is a single representative value per series with no replicate data available (Section 6), it is not possible to determine from this dataset alone whether the reversal reflects genuine grade-dependent behaviour at low steel fibre dosage or specimen-level variability that would average out with replicate testing.

4.5 Comparison with Existing Literature

The results of this study are broadly consistent with existing literature on steel and glass fibre reinforced concrete, which identifies fibre dosage as a parameter affecting post-cracking tensile and flexural performance. However, not all published data agrees with the monotonic 0.5%-to-1.5% strength gain observed here — some studies have reported that strength peaks at a certain dosage and then declines at higher dosages.

Additional detail from the source document: the identification of fibre dosage as a dominant parameter governing post-cracking tensile and flexural performance is attributed to Song and Hwang (2004). The pronounced steel-versus-glass gap observed specifically in the tension- and flexure-dominated tests, rather than in compression, is consistent with hybrid and multi-fibre reinforced cement composite research reporting that different fibre materials contribute distinct, complementary crack-control mechanisms depending on their stiffness and bond characteristics (Banthia and Nandakumar 2003). The peak-then-decline dosage pattern referenced above is drawn from a comparable shotcrete investigation over a wider 0–2.0% dosage range, where Liu et al. (2024) reported that steel fibre compressive strength peaked at a 0.5% dosage and declined at higher dosages, while glass fibre flexural strength peaked at 1.5% and declined beyond that point — attributed to fibre clustering and uneven dispersion at higher dosages. The present study's two-point dataset does not extend far enough to observe a comparable turning point; this is noted as an open question for the extended dosage range recommended in Section 7.

4.6 Relevance to Textile Reinforced Concrete

The results of this study are also relevant to textile reinforced concrete, which uses AR-glass or carbon textile fabric to replace or supplement conventional bar reinforcement. The study shows that discrete AR-glass fibre has a different reinforcement mechanism from continuous AR-glass mesh, and that the two should not be directly compared without further testing.

Additional detail from the source document: textile-reinforced concrete (TRC) has been reviewed extensively as a structural and strengthening material (Venigalla et al. 2022; Wu et al. 2023), with AR-glass textile specifically shown to improve the flexural load-carrying capacity of reinforced concrete beams when used as internal or external strengthening layers (Alhorani et al. 2023). These TRC studies use continuous, mould-placed or externally-bonded textile sheets rather than the discrete, randomly dispersed AR-glass fibre investigated in the present paper — a structurally distinct reinforcement geometry. Where continuous AR-glass mesh has shown a dosage-sensitive decline in strength with increasing reinforcement percentage in the related mesh-comparison programme referenced in Section 1 — attributed there to impeded matrix compaction through the mesh apertures at higher layer counts — the discrete AR-glass fibre series in the present study shows the opposite trend over the 0.5–1.5% range tested. This divergence indicates that generalisations about AR-glass reinforcement performance from one reinforcement geometry should not automatically be extended to the other without direct comparative testing.

5. Practical Applications

The discrete fibre reinforcement systems investigated in this study have a number of applications, including slab-on-grade flooring, precast and thin-section elements, corrosion-sensitive applications, and crack control in fly-ash blended concrete.

Steel fibre reinforced concrete is widely used in industrial floor slabs and pavements, where distributed crack control and improved impact/abrasion resistance are required; the compressive and flexural strength gains observed for the steel fibre series support this application.

AR-glass fibre, on the other hand, offers a corrosion-free alternative to steel fibre for concrete elements exposed to marine, chemical, or otherwise corrosive environments. This study quantifies the strength penalty of using AR-glass fibre, allowing designers to weigh that trade-off against corrosion risk.

The results also demonstrate that both fibre types remain viable reinforcement strategies within a lower-carbon, fly-ash-blended matrix, supporting their use in sustainable construction practice.

Additional detail from the source document, organised by application: (i) Industrial and slab-on-grade flooring — steel fibre reinforced concrete is widely used in industrial floor slabs and pavements where distributed crack control and improved impact/abrasion resistance are required without the labour cost of conventional bar or mesh placement; the gains observed for SF4 (M40, 1.5%) specifically support this application. (ii) Precast and thin-section elements — the panel flexural results indicate that both fibre types, and particularly steel fibre, improve the flexural performance of thin sections relative to a plain matrix, supporting use in precast panels, cladding, and other thin non-structural or semi-structural elements. (iii) Corrosion-sensitive applications — AR-glass fibre, being non-metallic, offers a corrosion-free alternative to steel fibre at a strength penalty this study quantifies directly (Table 7), so designers can weigh that trade-off against corrosion risk. (iv) Crack control in fly-ash blended concrete — since all mixes in this study incorporate 25% fly ash replacement, both fibre types are shown to remain effective within a lower-carbon, fly-ash-blended matrix.

- The use of fibre reinforcement systems can improve the crack control and post-cracking toughness of concrete.
- The results of this study can be used to inform the design of elements that require improved flexural performance.
- Further research is needed to understand the mechanisms of discrete fibre reinforcement and to explore their potential applications.
- The study highlights the importance of considering the reinforcement geometry when designing elements.
- The results of this study have implications for the development of construction materials and practices.

6. Limitations

- Full statistical data (standard deviation, coefficient of variation) is only available for cube compressive strength; equivalent data for split tensile, beam flexural, and panel flexural strength is not available, limiting the ability to assess the statistical significance of differences in those properties.
- Continuous load–deflection data was not recorded during beam or panel flexural testing — only the ultimate flexural strength and a qualitative failure-mode observation (beam intact vs. beam separated) were captured, so the post-cracking response shown in Figure 3b is a schematic illustration of the observed failure behaviour, not a measured curve.
- No unreinforced (plain concrete) control mix was tested, making it difficult to quantify how much the fibres improve strength relative to no reinforcement at all — only the two fibre types can be compared with each other.
- Only two dosage levels (0.5% and 1.5%) were examined; a 1.0% dosage level was not tested. Other research suggests that adding fibres can sometimes reduce strength at certain dosages, but this was not verified for the fibres used here.

- Detailed fibre geometry data (size and shape) is not available, making it harder to compare these results with other published research.
- No images of fibre dispersion within the concrete were captured, which would have helped explain why some configurations were stronger than others.
- This study only examined steel and AR-glass fibres; polypropylene fibres and other reinforcement types were not investigated.

Additional detail from the source document: this fibre programme is explicitly scoped away from polypropylene fibre series, mesh-only series, the six hybrid mesh-fibre combinations, and drop-weight impact testing — all of which are addressed separately in the wider experimental programme referenced in Section 1 and in Section 7 below.

7. Future Work

- Test concrete without any fibres to establish a plain-concrete baseline strength.
- Obtain detailed statistical data for tensile and flexural strengths, matching what is currently available for compressive strength.
- Test additional fibre dosage levels to better characterise the dosage-strength relationship.
- Investigate fibre-matrix bond and capture images of fibre dispersion within the concrete.
- Extend the comparison to other fibre reinforcement types.
- Test impact resistance of the fibre-reinforced concrete.

Additional detail from the source document: bond characterisation should specifically include pull-out testing of individual fibres from the matrix to quantify anchorage/bond strength directly, rather than relying only on bulk strength trends as an indirect indicator. Impact resistance testing should follow the ACI 544 drop-weight method. Future dosage testing should include the previously untested 1.0% level to interpolate between the current 0.5% and 1.5% data points, and should extend the dosage range further to check for the peak-then-decline behaviour reported elsewhere in the literature (Section 4.5). The comparison should also be extended to the polypropylene fibre series and the six hybrid mesh-fibre combinations excluded from the present paper's scope (Section 6), to determine how steel and AR-glass fibre performance sits relative to those alternatives within the same experimental programme.

8. Conclusions

- Steel fibres made the concrete stronger than AR-glass fibres in nearly all cases tested.
- Increasing fibre dosage generally made the concrete stronger, for both fibre types.
- The strongest concrete produced in this study used 1.5% steel fibre dosage at M40 grade.
- The effect of fibre type and the effect of fibre dosage do not always combine in a simply additive way.
- Differences between some series may not be statistically significant, and results should be interpreted with that caution in mind.
- Steel fibres help concrete stay in one piece even after cracking, unlike AR-glass fibre.

Overall, steel fibres outperform AR-glass fibres for maximising concrete strength, but AR-glass fibres remain a good option where corrosion resistance is a priority.

Additional quantitative detail from the source document: the M30/0.5% cube compressive comparison between steel and glass fibre was statistically indistinguishable ($p = 0.99$); only 2 of the 8 statistical comparisons tested reached significance at $\alpha = 0.05$ (Table 9), so most of the directional trends reported here should be treated as observed patterns rather than confirmed statistically significant effects at the current replicate count. The best steel fibre panel result (SF4, 4.81 MPa) was 67% above the weakest series overall (GF1, 2.88 MPa). Combining higher grade and higher dosage produced a small sub-additive (diminishing-returns) interaction of roughly 2–3% below the additive prediction, rather than a synergistic one, for the steel fibre series specifically (Section 4.3).

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