

Effect of Steel Fibre Length Variation on Compressive Strength of Ultra High-Performance Concrete Using Ultratech Ready Dry Mix

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Abstract—Ultra High-Performance Concrete (UHPC) offers compressive strengths exceeding 120 MPa and superior durability when reinforced with steel fibres. This study investigates the influence of steel fibre length variation specifically 10 mm, 25 mm, and 50 mm on the compressive strength development of UHPC prepared using Ultratech ready dry mix. Cube specimens (70×70×70 mm for 10 mm and 25 mm fibres; 100×100×100 mm for 50 mm fibres) were cast at Raina Industries Pvt. Ltd. and tested at 7, 14, and 28 days as per IS 516: Part 1: Sec 1: 2021 at Aqua Lab, Mira Road. All mixes exceeded the M-120 design grade at 28 days. At 28 days, 10 mm fibres achieved the highest average compressive strength of 127.2 N/mm², followed by 25 mm fibres at 125.4 N/mm², and 50 mm fibres at 123.3 N/mm². The results indicate that fibre length has a moderate but measurable influence on compressive performance, with shorter fibres offering better matrix dispersion and compressive efficiency, while longer fibres improve post-cracking toughness and energy absorption.

Index Terms—Compressive Strength; Fibre-Reinforced Concrete; M-120 Grade; Steel Fibre Length; UHPC; Ultratech Dry Mix

I. INTRODUCTION

Concrete remains the most widely used construction material globally, yet its inherent brittleness under tensile and flexural loading limits its application in demanding structural environments. Ultra High-Performance Concrete (UHPC) represents a significant advancement in cementitious materials technology, offering compressive strengths exceeding 120 MPa, extremely low porosity, and enhanced ductility when reinforced with steel fibres [1].

The incorporation of steel fibres in UHPC transforms its post-cracking behaviour by bridging developing micro-cracks, improving energy absorption, and reducing brittleness. Among fibre parameters, fibre length is a critical variable: it governs crack-bridging efficiency, fibre pull-out resistance, mixing workability, and fibre dispersion uniformity within the matrix [2].

This study uses Ultratech ready dry mix a commercially available UHPC formulation ensuring results are directly applicable to practical construction scenarios. Steel fibres of three lengths (10 mm, 25 mm, and 50 mm) were used at a constant dosage to isolate the effect of fibre length on compressive strength development at 7, 14, and 28 days.

II. LITERATURE REVIEW

Singh, Sharma & Gupta (2019) [1] investigated crack control in UHPC with 12 mm, 25 mm, and 50 mm steel fibres. Longer fibres provided superior crack bridging under tensile stress, while shorter fibres ensured better dispersion. The study concluded that appropriate fibre length selection balances structural performance and workability.

Akeed (2022) [2] demonstrated that fibre length, shape, and volume fraction jointly determine crack control efficiency in UHPC. Optimising all three parameters together yields superior structural outcomes compared to adjusting them in isolation.

Ullah (2022) [3] conducted a state-of-the-art review confirming that fibre length directly governs crack-bridging capacity and energy absorption, establishing it as a primary design parameter.

Jiao (2022) [4] compared UHPC beams reinforced with short, medium, and long fibres, concluding that toughness-critical applications benefit from longer fibres, while precision-cast elements perform better with shorter fibres.

Tayeh (2022) [5] found that hooked-end fibres offer greater post-cracking toughness than straight fibres, with fibre volume fraction as the dominant factor in flexural strength enhancement.

Hung (2021) [6] concluded that optimum fibre length must balance strength and workability in practical UHPC design.

III. OBJECTIVES

1. To prepare UHPC specimens reinforced with steel fibres of 10 mm, 25 mm, and 50 mm lengths under controlled casting conditions.
2. To evaluate and compare compressive strength values at 7-day, 14-day, and 28-day curing ages using a Compression Testing Machine (CTM).
3. To identify the fibre length that yields the most effective compressive strength performance and observe failure patterns as a function of fibre length.

IV. MATERIALS AND METHODOLOGY

A. Materials

Ultratech Ultra High-Performance Dry Mix Concrete was used as the primary material a factory-prepared, pre-blended formulation that eliminates batching variability and ensures consistent matrix composition across all specimens. Hooked-end steel fibres of three lengths were used: 10 mm (short), 25 mm (medium), and 50 mm (long), at a constant dosage of 0.100 kg per 10 kg of dry mix. Potable water (0.750 kg per 10 kg dry mix) and a PCE-based superplasticiser (0.090 kg per 10 kg dry mix) were used consistently across all batches.

B. Specimen Design

A total of 27 cube specimens were cast 9 per fibre length, 3 per curing age. Moulds of 70×70×70 mm were used for 10 mm and 25 mm fibres; 100×100×100 mm moulds were used for 50 mm fibres to accommodate fibre length without edge disturbance. The single variable across all batches was fibre length.

Table I: Specimen Distribution

Fibre Length	Cube Size (mm)	No. of Specimens
10 mm	70×70×70	9
25 mm	70×70×70	9
50 mm	100×100×100	9

C. Casting and Curing

Casting was carried out at Raina Industries Pvt. Ltd., Vasai on 3–4 April 2026. Dry mixing was performed for 2–3 minutes, fibres were added incrementally to prevent clumping, and water with superplasticiser was introduced gradually. Manual compaction and vibration removed entrapped air. Specimens were demoulded after 24 hours and immersed in water tanks for continuous curing at room temperature.

D. Testing Procedure

Compressive strength testing was conducted at Aqua Lab, Mira Road, Thane using a standard hydraulic Compression Testing Machine (CTM) as per IS 516: Part 1: Sec 1: 2021. Tests were performed at 7 days (10 April 2026 for 25 mm; 11 April 2026 for 10 mm and 50 mm), 14 days (17 April 2026 for 25 mm; 18 April 2026 for 10 mm and 50 mm), and 28/29 days (2 May 2026 for all groups).

$$\text{Compressive Strength (N/mm}^2\text{)} = \text{Failure Load (N)} / \text{Cross-Sectional Area (mm}^2\text{)}$$

V. RESULTS AND DISCUSSION

A. 7-Day Compressive Strength Results

Seven-day testing was completed on 10 April 2026 for 25 mm specimens and 11 April 2026 for 10 mm and 50 mm specimens (Aqua Lab Report Nos. 26/09861, 26/09660, 26/09862). All groups achieved compressive strengths in the range of 79.6 to 82.4 N/mm².

Table II: 7-Day Compressive Strength Results

Fibre	Specimen	Age (d)	Size (mm)	Load (kN)	CS (N/mm ²)	Avg. (N/mm ²)
10 mm	S1	7	70×70	401.12	81.86	
10 mm	S2	7	70×70	398.44	81.31	82.4
10 mm	S3	7	70×70	412.41	84.17	
25 mm	S1	7	70×70	389.11	79.41	

25 mm	S2	7	70×70	394.18	80.44	79.6
25 mm	S3	7	70×70	386.34	78.84	
50 mm	S1	7	100×100	795.11	79.51	
50 mm	S2	7	100×100	811.29	81.13	80.8
50 mm	S3	7	100×100	817.24	81.72	

B. 14-Day Compressive Strength Results

Fourteen-day testing was completed on 17 April 2026 for 25 mm specimens and 18 April 2026 for 10 mm and 50 mm specimens (Aqua Lab Report Nos. 26/10395, 26/10394, 26/10396). A significant strength gain of 27–32% was observed from 7 to 14 days across all groups, confirming rapid cement hydration and pozzolanic reaction.

Table III: 14-Day Compressive Strength Results

Fibre	Spec.	Age (d)	Size (mm)	Load (kN)	CS (N/m ²)	Avg. (N/m ²)
10 mm	S1	14	70×70	511.27	104.34	
10 mm	S2	14	70×70	519.66	106.05	106.0
10 mm	S3	14	70×70	527.42	107.64	
25 mm	S1	14	70×70	509.42	103.96	
25 mm	S2	14	70×70	512.52	104.60	104.7
25 mm	S3	14	70×70	517.34	105.58	
50 mm	S1	14	100×100	1024.42	102.44	
50 mm	S2	14	100×100	1027.13	102.71	103.1
50 mm	S3	14	100×100	1041.54	104.15	

C. 28-Day Compressive Strength Results

Twenty-eight-day testing was completed on 2 May 2026 (Aqua Lab Report Nos. 26/11610, 26/11609, 26/11611). All mixes exceeded the M-120 design grade, confirming the effectiveness of Ultratech ready dry mix with steel fibre reinforcement.

Table IV: 28-Day Compressive Strength Results

Fibre	Spec.	Age (d)	Size (mm)	Load (kN)	CS (N/m ²)	Avg. (N/m ²)
10 mm	S1	28	70×70	626.42	127.84	
10 mm	S2	28	70×70	631.54	128.89	127.2
10 mm	S3	28	70×70	611.57	124.81	
25 mm	S1	29	70×70	620.11	126.55	
25 mm	S2	29	70×70	609.24	124.33	125.4
25 mm	S3	29	70×70	613.41	125.19	
50 mm	S1	28	100×100	1241.54	124.15	
50 mm	S2	28	100×100	1224.41	122.44	123.3
50 mm	S3	28	100×100	1234.52	123.45	

D. Consolidated Strength Development

Table V: Consolidated Strength Development (N/mm²)

Fibre Length	7-Day Avg.	14-Day Avg.	28-Day Avg.	7→14 Gain	14→28 Gain
10 mm	82.4	106.0	127.2	+28.6%	+20.0%
25 mm	79.6	104.7	125.4	+31.5%	+19.8%
50 mm	80.8	103.1	123.3	+27.6%	+19.6%

Key trends observed from the experimental results:

1. All UHPC mixes exceeded M-120 grade at 28 days across all fibre lengths tested.
2. The highest strength gain (27–32%) occurred between 7 and 14 days, reflecting rapid C-S-H gel formation and accelerated pozzolanic reaction within the dense UHPC matrix.
3. The gain from 14 to 28 days was more gradual (~19–20%), consistent with progressive matrix maturation and continued hydration product densification.
4. At 28 days, 10 mm fibres performed best in compression (127.2 N/mm²) due to superior matrix integration and packing density within the fine-grained UHPC matrix.
5. 50 mm fibre specimens exhibited enhanced post-cracking toughness and more distributed crack patterns, though 28-day compressive strength was marginally lower (123.3 N/mm²).

Specimen size effects must be noted: 50 mm fibre specimens were cast in 100×100×100 mm cubes while 10 mm and 25 mm specimens used 70×70×70 mm cubes. Larger specimens tend to report marginally lower compressive strength due to greater probability of encountering a weaker failure plane. This size effect partially accounts for the slightly lower 28-day average of the 50 mm group and should be considered in direct cross-group comparisons.

VI. CONCLUSION

This experimental study confirms that UHPC prepared using Ultratech ready dry mix consistently achieves compressive strengths above 120 MPa at 28 days across all three steel fibre lengths tested. The principal findings are:

1. At 28 days, 10 mm fibres yielded the highest average compressive strength (127.2 N/mm²), followed by 25 mm fibres (125.4 N/mm²) and 50 mm fibres (123.3 N/mm²). The differences are within typical experimental variation (≈2–4 MPa).
2. Steel fibre length has a moderate but measurable influence on compressive strength. Shorter fibres improve matrix dispersion and packing density, favouring compressive performance. Longer fibres enhance post-cracking toughness and energy absorption, critical for applications under tensile or impact loading.
3. The use of a commercial ready dry mix demonstrates that UHPC technology is practically accessible without specialised laboratory batching infrastructure, making it viable for site-level deployment.

Future work should extend testing to split tensile and flexural strength, explore higher fibre volume fractions, and investigate microstructural bonding mechanisms through SEM analysis. A uniform specimen size across all fibre lengths is also recommended to eliminate size-effect variables in comparative studies.

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