MSW MANAGEMENT -Multidisciplinary, Scientific Work and Management Journal
ISSN: 1053-7899
Vol. 36 Issue 1s, 2026, Pages: 1866-1872

Performance Evaluation of Fibre-Reinforced Cementitious Grout for Structural Rehabilitation

Mr Nandeesh M, Research Scholar, Department of Civil Engineering, UVCE, Bengaluru, Karnataka, India.
Dr Kiran T, Associate Professor, Department of Civil Engineering, UVCE, Bengaluru, Karnataka, India.
Dr K G Guptha, Professor (Retired), Department of Civil Engineering, Goa College of Engineering, Goa, India.

ABSTRACT

In order to improve the mechanical performance of cementitious grout matrices in relation to structural rehabilitation and repair projects, this study investigates cementitious grout matrices reinforced with polyolefin fiber (Mape fiber BG55). Three distinct phases comprised the experiment program: (1) optimization of grout composition by experimenting with non-shrink admixtures; (2) testing of Polyolefin fiber configurations with different aspect ratios at a constant fiber dosage; and (3) combined evaluation of optimized grout-fibre systems. Compressive strength and flexural strength were evaluated during different curing times (3, 7, and 28 days). Findings showed that better performance at 28 days with Quarter length fibres (aspect ratio 17.19) with optimized grout (50.15 N/mm^2 compressive strength (11.72% increase) and 5.82 N/mm^2 flexural strength (34.72% increase)) was attained relative to Control Specimen. These findings show that there is a relationship between optimised grout composition and optimal fibre geometry. These improvements can be attributed to enhanced fibre–matrix bonding, effective crack-arresting mechanisms, and a refined microstructural framework. The findings provide empirical evidence that a well-balanced combination of grout composition and fibre geometry leads to the development of high-performance cementitious materials, making them particularly suitable for durable structural repair and rehabilitation applications.

Keywords: Cementitious grout, fibre reinforcement, polyolefin fibre- Mape fibre BG55, aspect ratio, compressive strength, flexural strength, structural rehabilitation.

1. INTRODUCTION

In civil infrastructure systems, grouting is crucial for functions like void filling, crack sealing, and improving load transfer. However, there are inherent drawbacks to conventional cementitious grouts, such as low tensile capacity, poor ductility, and limited resistance to crack initiation and propagation. The brittle nature of unreinforced grout matrices frequently jeopardizes long-term durability and structural integrity in rehabilitation and repair situations. Therefore, fixing these flaws is crucial to enhancing the functionality and lifespan of repaired structures. The inclusion of synthetic fibre has been one of the strategies that have come out to overcome these performance limitations.

According to recent research, improving the composition of grout greatly improves its workability and compressive strength. Setting behavior and strength development are significantly influenced by factors like binder type, water-to-binder ratio, and the use of chemical admixtures. In such a scenario, adding synthetic fibers, especially polyolefin fibers has proven effective in improving ductility and mitigating microcrack initiation and propagation. One important factor affecting the composite behaviour of fiber-reinforced grout matrices is fibre geometry, particularly the aspect ratio. The aspect ratio controls the overall toughness of the composite system, the uniformity of fibre dispersion, and the effectiveness of stress transfer between the fibre and matrix. Although fiber-reinforced concrete has been the subject of much research, the impact of fibre aspect ratio in cementitious grout systems has received relatively little attention. Therefore, more research is needed to completely comprehend its function in improving grout performance. This study incorporates optimization of grout with systematic analysis of fibre aspect ratios to come up with improved grout systems. Additionally, uses mechanical tests and analysis of performance to define fibre-matrix system.

1.1 Literature Review

Effects on Workability, Dispersion and Fibre Factor

Many studies consider aspect ratio together with fibre volume through a fibre factor (FF) that scales with volume × aspect ratio. For PP fibre-reinforced self-consolidating mortar, there is an optimal FF range; below a critical FF ≈ 90–100 fibres have negligible effect, while above a dense fibre factor the mixture loses stability from clustering and segregation, reducing the mechanical properties (Mehdipour et al., 2013; Si et al., 2020; Li et al., 2018). For PVA mortars, FF < 100 has little effect on rheology and damages the matrix, 100–400 gives good dispersion and enhanced strength, while FF > 400 results in clustering and reduces workability and strength (Si et al., 2020). Similar FF-based models for PP mortars calculate workability as a function of water film thickness and FF, and indicate that increasing aspect ratio with fixed volume reduces flow significantly and increases blocking risk (Li et al., 2018). All of these results suggest that longer/thinner PP or polyolefin fibres can only be mechanically effective if their dispersion is maintained by keeping FF below a material-specific upper limit.

Compressive Strength and Modulus

For conventional PP fibres in mortars and concretes, aspect ratio has little to no effect on compressive strength. Addition of PP fibres with varying aspect ratios resulted in minor reductions or no significant alterations of the compressive strength and modulus of elasticity of mortars, since the introduction of voids and weak interfaces when over-doseing the fibres has negative effects on strength (Topçu et al., 2017; Broda & Brachaczek, 2015; Bagherzadeh et al., 2012). In PP-reinforced concrete, increasing aspect ratio (by using longer fibres at any given volume) mainly enhances toughness and crack control, but does not affect compressive strength (Bagherzadeh et al., 2012). In review work on geopolymer concretes, it was found that at optimal PP volume, increasing PP fibre aspect ratio generally reduces compressive strength, unlike for steel fibres which improve compressive strength as a function of aspect ratio (Wang et al., 2023). Macro-polyolefin fibres in geopolymer concrete at a relatively low aspect ratio achieved very high fracture energy but only marginally reduced compressive strength, suggesting that moderate aspect ratios can already trigger useful crack-bridging in compression-dominated loading (Noushini et al., 2018).

Flexural/Tensile Strength, Toughness and Ductility

Aspect ratio plays a more decisive role in tensile-related properties:

- In PP-reinforced mortars, fibres do not affect compressive strength but increase bending strength drastically, and the range of improvement depends on fibre geometry and fibrillation; fibrillated PP with effective crack-bridging yields the greatest flexural improvements (Broda & Brachaczek, 2015).
- For standard polypropylene fibres, greater availability in the matrix (higher effective aspect ratio) increases splitting tensile and flexural strengths by providing more capacity for micro-crack bridging (Bagherzadeh et al., 2012).
- In mortars reinforced with corrugated plastic fibres of aspect ratios of 37 and 46, flexural strength at low fibre contents (0.5 wt%) showed clear flexural improvements as a function of fibre aspect ratio: higher AR raised flexural strength as high as ~68%, while lower AR produced much smaller effects (Gullì et al., 2022).
- For PP and PE blended fibres in mortars, lower effective aspect ratio combined with a large cross-section and high surface roughness resulted in superior mechanical properties: at a high volume fraction compressive strength increased by ~38% and flexural strength by ~40% Silva et al. attribute this to “strong mechanical anchorage and self-fibrillation,” indicating that geometry can compensate for non-ideal aspect ratios when bond is strong.

In geopolymer mortars and concretes, review work confirms that for PP fibres at optimal volume, smaller aspect ratios yield higher splitting tensile and flexural strengths than slender fibres which tend to ball and perform poorly (Noushini et al., 2018; Wang et al. 2023). In contrast with this divergence, moderate to high aspect ratios improve tensile strength for steel fibres. This finding indicates that the effectiveness of aspect ratio as a variable changes depending on the type of fibre used, surface characteristics and stiffness.

Effect of Aspect Ratio in Hybrid & Macro-Polyolefin Fibre Systems

Hybrid systems and macro-polyolefin fibres further establish the effect of aspect ratio on toughness:

- Macro-polyolefin fibres with relatively low aspect ratios in geopolymer concrete yielded the highest fracture energy among synthetic fibres due to sufficient length without excess (Noushini et al., 2018).
- Hybrid polyproplylene systems combining different lengths (therefore different effective aspect ratios) showed significant improvement in fracture toughness and specific fracture energy in high-strength concrete, since longer fibres bridged macro-cracks and shorter ones restrained micro-cracks; however excessive total fibre content reduced strength through clustering Hrabová et al. (2025).

Conclusions & Design Implications Drawn from Synthesised Results

Synthesising findings for PP/polyolefin reinforced mortars/concretes et al., several consistent findings emerge:

- Workability limits maximum usable aspect ratio at a given fibre volume (top boostoe); too high FF causes clustering and reduced strength (Mehdipour et al., 2013; Si et al. 2020; Li et al., 2018)
- Compressive strength shows limited response to changes in aspect ratio; it may be reduced at high AR
- (Topçu et al., 2017; Broda & Brachaczek, 2015; Bagherzadeh et al. 2012; Wang et al. 2023)
- Flexural/tensile strength shows clear improvements as a function of increasing aspect ratio (Silva et al., 2013; Broda & Brachaczek, 2015; Bagherzadeh et al. 2012; Wang et al. 2023; Gullì et al., 2022)
- For relatively flexible polymeric fibres (PP/polyolefine), moderate aspect ratios combined with increased surface roughness rather than greater slenderness outperform greater aspect ratios (Silva el at, 2013; Noushini et al., 2018; Gullì et al. ,2022). Due to the potential of 3D printing to revolutionize the construction industry in terms of automation and sustainability, additive manufacturing in construction has garnered significant attention [9]. Alumina silicates have been proven to play a key role in enhancing the fresh and hardened properties of self-consolidating concrete [10]. The use of agro-industrial waste, such as bagasse ash, in the production of adobe bricks has led to improvements in strength and sustainability in the construction of bricks [11]. Alumina silicates in construction concrete have been proven to exhibit superior performance in high temperatures [12]. The incorporation of demolished construction waste with pozzolanic materials in the production of bricks has been proven to significantly increase the strength of the resulting bricks [13]. These results indicate that for polypropylene and polyolefine-reinforced mortars/concretes the best mechanical properties will be obtained using materials where FF stays below the threshold for clustering/breakdown (indicating the importance of dispensing effect), as well as selecting AR values that enhance bond while giving good dispersion yet does not exceed sizes that lead to negative effects on workability.

2. Materials

Ordinary Portland Cement (OPC) of 43 grade (Zuari make), Conforming to IS: 269 -2015), locally sourced river sand (IS 383:2016 Zone II), potable water (IS 456:2000), and Conbextra GP2 (Fosroc Make) cementitious grout were used as primary materials in this study. The fibre reinforcement, Polyolefin fibres (Mape Fibre BG 55) were incorporated with fixed dosage and with varying aspect ratios. All materials were evaluated according to relevant BIS and ASTM standards to confirm compliance and suitability for general purpose grout.

The detailed physical and mechanical properties of the cement, grout, and fibres, as well as the aspect ratios used, are presented in Tables 1–4 for reference.

Table 1. Physical Characteristics of Ordinary Portland Cement

Sl. No.	Parameter	Results
1	Normal consistency	31.00%
2	Specific gravity	3.15
3	Fineness, Blains	340 m^2/kg
4	Setting time a) Initial time b) Final time	 45 minutes 215 minutes
5	Soundness	0.5 mm (in Le Chatelier Test)

Table 2. Physical Characteristics of Cementitious Grout (Conbextra GP2)

Sl. No.	Parameter	Results
1	Flowability	15 seconds
2	Bleeding	0.1%
3	Initial Setting Time	25 minutes
4	Final Setting Time	145 minutes
5	Expansion	1%
6	Shrinkage	0.01% shrinkage

Table 3. Physical Properties of Fibre (Mape fibre BG 55)

Name of the Fibre	Mape fibre BG 55
Type of Fibre	Polyolefin
Length	55 mm
Width	0.8 mm
Melting Point	160 °C
Density	0.91 g/cm^3
Tensile Strength	525 MPa
Modulus of Elasticity	6000 MPa

Table 4. Aspect Ratios of Polyolefin Fibres Generated in the lab from full length fibres

Aspect Ratio Designation	Fibre Length (mm)	Aspect Ratio Value
Manufactured Length (L)	55	68.75
L/2	27.5	34.38
L/4	13.75	17.19
L/8	6.875	8.60

2.1 Mix Proportions and Sample Preparation

Three distinct grout mixes were prepared across the experimental phases: a Control Specimen (CS) using 100% Ordinary Portland Cement (OPC), river sand, and water-cement ratio (w/c) of 0.50; an Optimized Grout incorporating CS with 0.45% Conbextra GP2 non-shrink admixture by weight of cement; and Fibre-Reinforced Grout Composites based on the optimized grout plus 0.5% Polyolefin fibres (Mape Fibre BG55) by weight of cementitious material, with aspect ratios as specified in Table 4. Detailed mix proportions for all variants are presented in Table 5 below. Specimens were prepared following IS 4031 (Part 6): 1988 procedures. Compressive strength cubes (70.6 mm side) and flexural prisms (160 × 40 × 40 mm) were cast in triplicate for each mix and curing age, compacted using a table vibrator for 30 seconds, demolded after 24 hours, and subjected to water immersion curing at 27 ± 2°C.

Table 5: Mix Proportions by Weight Ratio (Cement : Sand : Water) for Grout Composites

Mix ID	Cement : Sand : Water	Cementitious Grout: (% cement wt)	Fiber Dosage (% cement wt)	Aspect Ratio
Control Specimen (CS)	1 : 1.25 : 0.50	0	0	-
Grout	1 : 1.25 : 0.50	0.45	0	-
L + Grout	1 : 1.25 : 0.50	0.45	0.5	68.75
L/2 + Grout	1 : 1.25 : 0.50	0.45	0.5	34.38
L/4 + Grout	1 : 1.25 : 0.50	0.45	0.5	17.19
L/8 + Grout	1 : 1.25 : 0.50	0.45	0.5	8.60

3. EXPERIMENTAL TESTING AND RESULTS

3.1 Compressive Strength Assessment

Compressive strength testing was conducted at 3, 7, and 28-day curing intervals using a calibrated compression testing machine operating at constant loading rate at 2.9 kN/s.

Table 6: Compressive Strength of Grout Mixes at Different Curing Ages (N/mm^2)

Mix Designation	3-Day Strength (N/mm²)	7-Day Strength (N/mm²)	28-Day Strength (N/mm²)
Control Specimen (CS)	23.53	33.58	44.89
CS+Grout	24.18	34.45	45.98
Strength Increase (%)	2.76	2.59	2.43

Table 7: Compressive Strength of Fibre-Reinforced Specimens at Various Curing Ages (N/mm^2)

Fibre Configuration	3-Day (N/mm²)	7-Day (N/mm²)	28-Day (N/mm²)	Percentage of Improvement
Control Specimen	23.53	33.58	44.89	Baseline
L	24.95	35.92	46.69	4.00
L/2	25.80	36.22	46.90	4.47
L/4	26.45	36.83	47.58	5.99
L/8	25.68	35.54	46.81	4.27

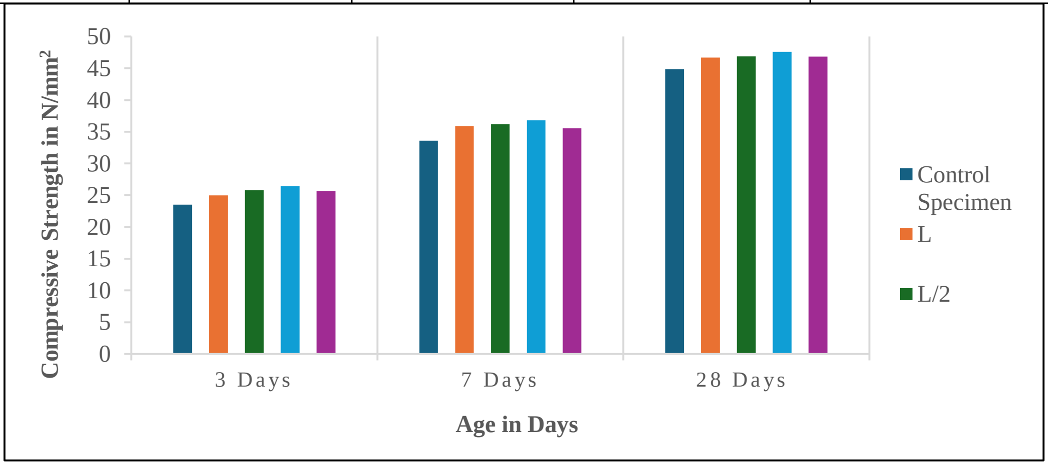

Figure 1: Compressive Strength of Fibre-Reinforced Cement Mortar (N/mm^2)

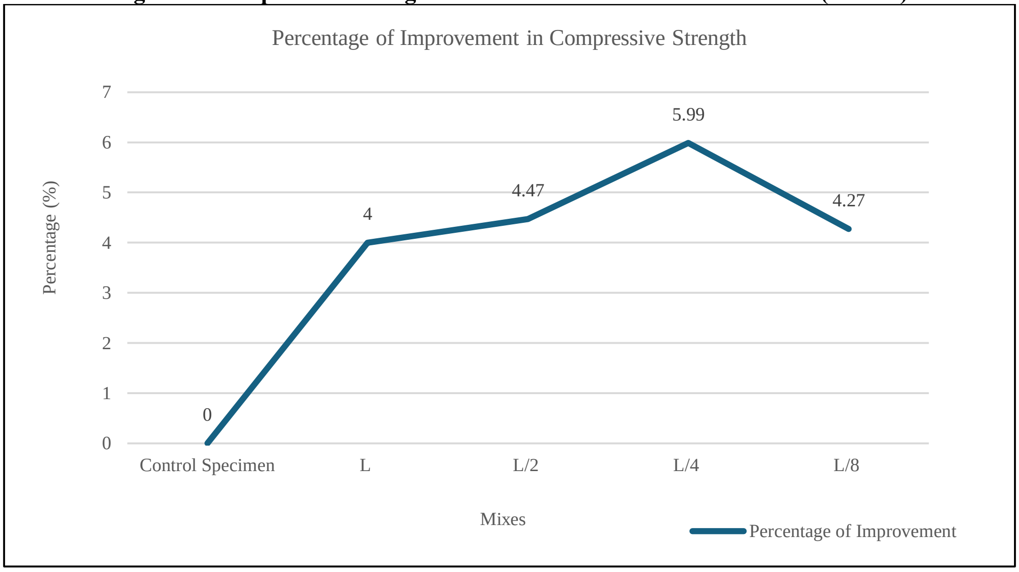

Figure 2: Percentage improvement of Fibre-Reinforced Cement Mortar

Table 8: Compressive Strength of Grout Composites with Fibres (N/mm²)

Mix Designation	3-Day (N/mm²)	7-Day (N/mm²)	28-Day (N/mm²)	Percentage of Improvement over Control Specimen	Percentage of Improvement over Optimized Grout (Grout)
Control Specimen	23.53	33.58	44.89	Baseline	—
L + Grout	25.18	36.25	48.55	8.15	5.59
L/2 + Grout	26.01	36.84	49.32	9.80	7.26
L/4 + Grout	26.77	37.24	50.15	11.72	9.06
L/8 + Grout	26.05	37.08	47.36	5.50	3.00

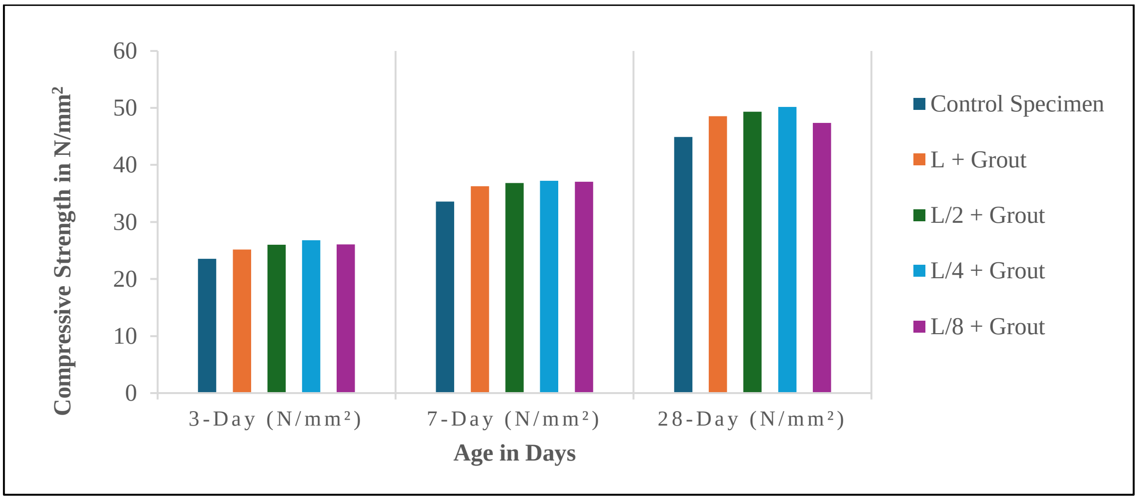

Figure 3: Compressive Strength of Grout Composites (N/mm²)

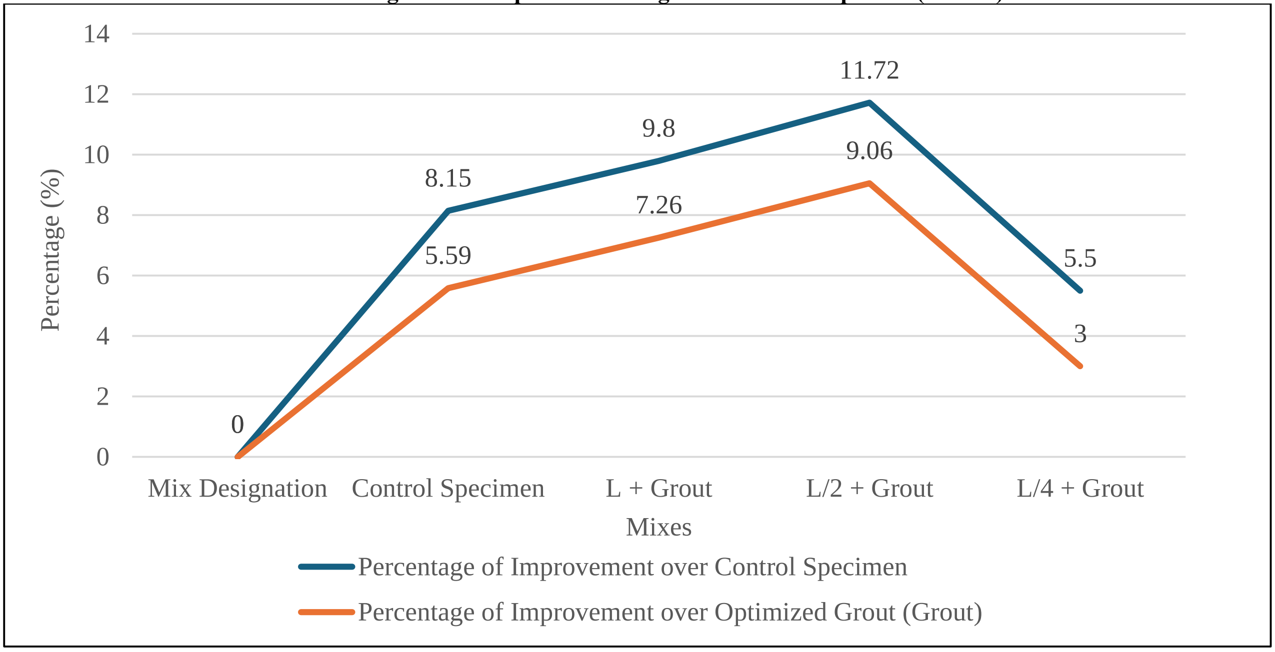

Figure 4: Percentage Improvement of Grout Composites

3.2 Flexural Strength Assessment

Flexural strength testing employed three-point bending methodology on prism specimens.

Table 9: Flexural Strength of Grout Mixes at Different Curing Ages (N/mm²)

Mix Designation	3-Day Strength (N/mm²)	7-Day Strength (N/mm²)	28-Day Strength (N/mm²)
Control Specimen	2.02	3.50	4.32
CS + Grout	2.66	3.65	4.45
Strength Increase (%)	3.16	4.29	3.00

Table 10: Flexural Strength of Fibre-Reinforced Specimens at Different Curing Ages (N/mm²)

Fibre Configuration	3-Day (N/mm²)	7-Day (N/mm²)	28-Day (N/mm²)	Percentage of Improvement
Control Specimen	2.02	3.50	4.32	Baseline
L	3.17	3.92	4.68	8.33
L/2	3.31	4.36	4.76	10.19
L/4	3.55	4.51	4.93	14.12
L/8	3.26	4.22	4.77	10.42

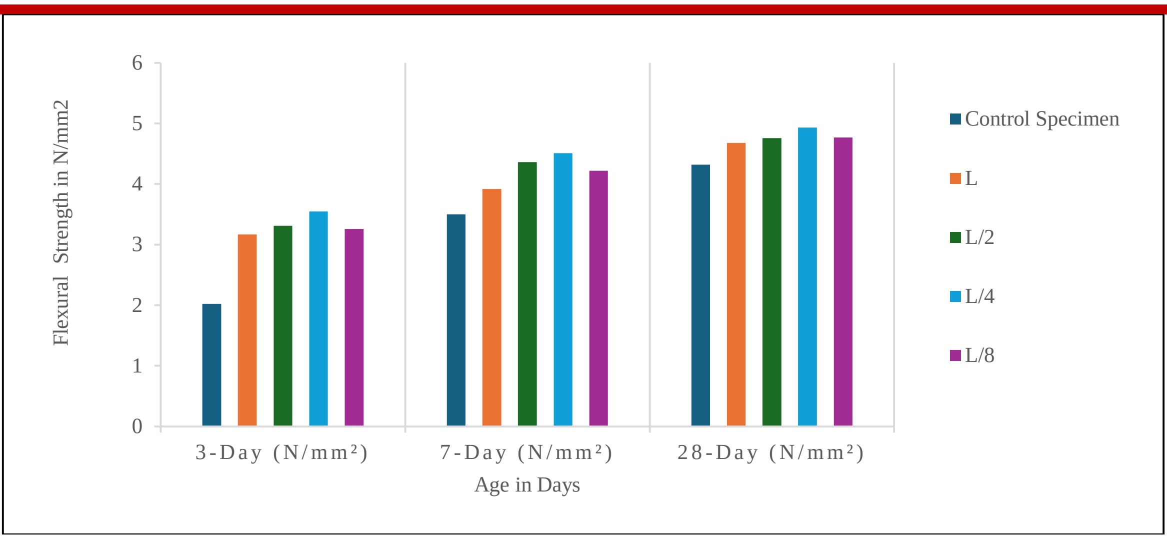

Figure 5: Flexural Strength of Fibre-Reinforced Cement Mortar (N/mm^2)

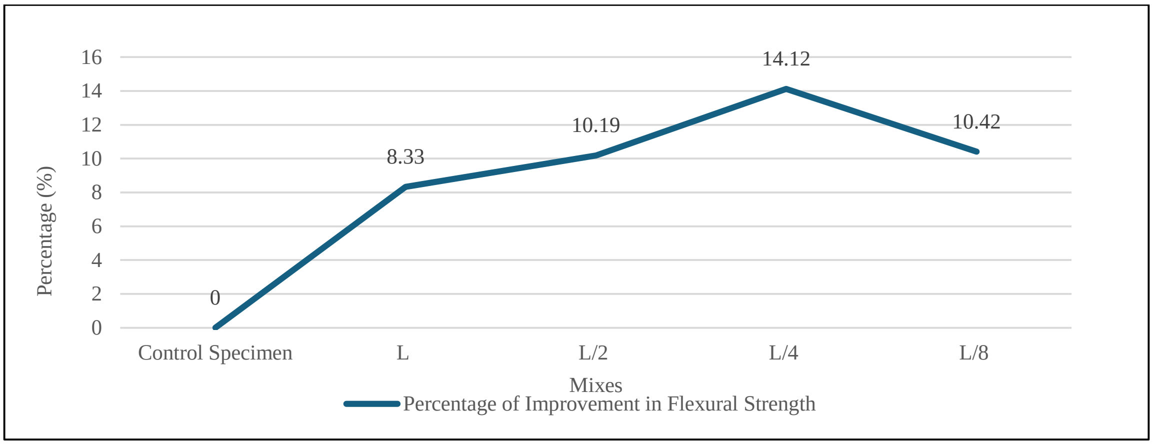

Figure 6: Percentage improvement of Fibre-Reinforced Cement Mortar

Table 11: Flexural Strength of Grout Composites with Fibres (N/mm^2)

Mix Designation	3-Day (N/mm²)	7-Day (N/mm²)	28-Day (N/mm²)	Percentage of Improvement over Control Specimen	Percentage of Improvement over Optimized Grout
Control Specimen	2.02	3.50	4.32	Baseline	—
L + Grout	3.52	4.45	5.16	19.44	15.96
L/2 + Grout	3.78	4.76	5.37	24.31	20.67
L/4 + Grout	4.12	5.02	5.82	34.72	30.78
L/8 + Grout	3.95	4.85	5.56	28.70	24.94

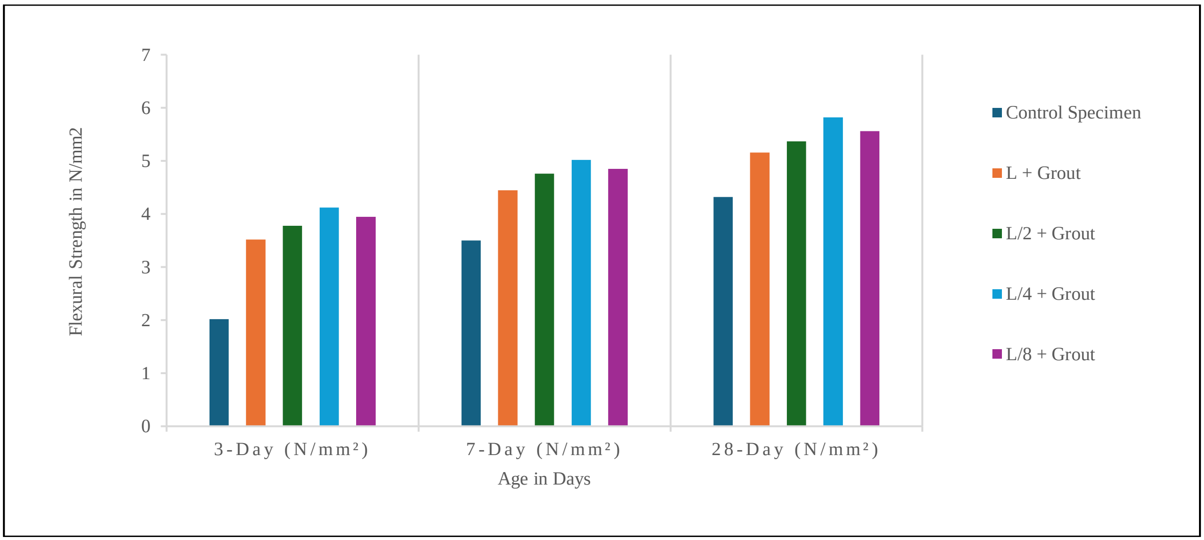

Figure 7: Flexural Strength of Grout Composites (N/mm^2)

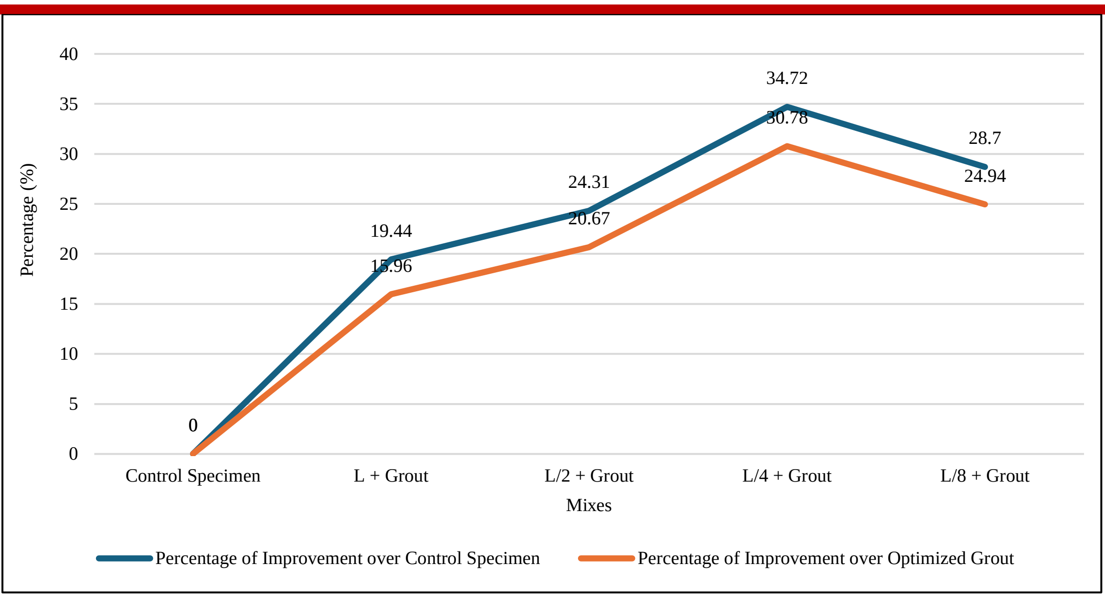

Figure 8: Percentage Improvement of Grout Composites

4. INTERPRETATION AND DISCUSSION

The experimental outcomes demonstrate that while individual grout optimization (2.43% compressive, 3.00% flexural gains) and fibre reinforcement (L/4: 5.99% compressive, 14.12% flexural improvements) each contribute meaningfully to mechanical performance, their synergistic combination yields optimal results, with L/4 fibres (aspect ratio 17.19) in optimized grout achieving 11.72% compressive (50.15 N/mm²) and 34.72% flexural (5.82 N/mm²) enhancements that meet crack resistance targets for structural repair applications. This superior L/4 performance reflects optimal balance between fibre length for effective matrix bonding and dispersion uniformity, avoiding clumping issues of longer L-L/2 fibres and inadequate crack-bridging capacity of shorter L/8 fibres, while early-age strength gains (6.24% compressive at 3 days) confirm accelerated hydration benefits. The consistent L/2-L/4 superiority establishes an intermediate aspect ratio domain (34.38-17.19) for the practical design window for OPC-based repair grouts.

5. CONCLUSION

This investigation systematically enhanced cementitious grout performance for structural rehabilitation through a three-phase optimization, culminating in a synergistic L/4–optimized grout system that achieved peak 28-day strengths of 50.15 N/mm² in compression (11.72% increase) and 5.82 N/mm² in flexure (34.72% increase) relative to the control mix. These gains exceed the simple superposition of Phase 1 matrix refinement with 0.45% Conbextra GP2 (2.43% compressive, 3.00% flexural increase) and Phase 2 fibre reinforcement with L/4 polyolefin fibres at 0.5% volume fraction (5.99% compressive, 14.12% flexural increase), underscoring a clear synergy between optimized grout composition and fibre geometry.

The adopted AR notation system (L: 68.75, L/2: 34.38, L/4: 17.19, L/8: 8.60) provides a practical framework for specifying fibre geometry, with the intermediate L/2–L/4 range (34.38-17.19) identified as optimal for balancing fibre–matrix bonding efficiency and mix workability in OPC-based grout with w/c = 0.50 tested in accordance with IS 4031. Within this domain, L/4 fibres (13.75 mm length, aspect ratio 17.19) combined with 0.45% Conbextra GP2 admixture emerge as the recommended specification for durable structural repair applications, while future work should validate long-term field durability and extend the findings to other grout chemistries and fibre volume fractions.

References

1. Azandariani, M. G., Vajdian, M., Asghari, K., & Mehrabi, S. (2023). Mechanical properties of polyolefin and polypropylene fibres-reinforced concrete An experimental study. Composites Part C: Open Access, 12, 100410.
2. Alberti, M. G., Enfedaque, A., Gálvez, J. C., & Picazo, A. (2020). Recent advances in structural fibre-reinforced concrete focused on polyolefin-based macro-structrural fibres. Materiales de Construcción, 70(337), e206.
3. Badawy, M. M., & Anan, A. I. (2023). Impact of addition of macro fibres on the mechanical properties of concrete. Journal of Al-Azhar University Engineering Sector, 18(67), 371–385.
4. Hassanzadeh, M., Madandoost, R., & Faghihmaleki, H. (2022). Study of the polyolefin fibres effect on the properties of fresh and hardened concrete. Structural Integrity and Life, 22(2), 211–217.
5. Laxmi, G., & Patil, S. G. (2022). Effect of fibre types, shape, aspect ratio and volume fraction on properties of geopolymer concrete—A review. Materials Today: Proceedings, 65, 1086–1094.
6. Li, B., Xu, L., Shi, Y., Chi, Y., Liu, Q., & Li, C. (2018). Effects of fibre type, volume fraction and aspect ratio on the flexural and acoustic emission behaviors of steel fibre reinforced concrete. Construction and Building Materials, 187, 699–711.
7. Yoo, D.-Y., Kim, S., Park, G.-J., Park, J.-J., & Kim, S.-W. (2017). Effects of fibre shape, aspect ratio, and volume fraction on flexural behavior of ultra-high-performance fibre-reinforced cement composites. Composite Structures, 174, 375–388.
8. Zych, T., & Krasodomski, W. (2016). Polyolefin fibres used in cementitious composites—manufacturing, properties and application. Technical Transactions—Civil Engineering, 3-B/2016, 155–170.
9. Nair, A., Aditya, S. D., Adarsh, R. N., Nandan, M., Dharek, M. S., Sreedhara, B. M., Prashant, S. C., & Sreekeshava, K. S. (2020). Additive Manufacturing of Concrete: Challenges and opportunities. In IOP Conference Series: Materials Science and Engineering (Vol. 814, Issue 1, p. 012022). IOP Publishing. https://doi.org/10.1088/1757-899x/814/1/012022
10. Dharek, M.S., Sunagar, P., Bhanu Tej, K.V., Naveen, S.U. (2019). Fresh and Hardened Properties of Self-consolidating Concrete Incorporating Alumina Silicates. In: Das, B., Neithalath, N. (eds) Sustainable Construction and Building Materials. Lecture Notes in Civil Engineering , vol 25. Springer, Singapore. https://doi.org/10.1007/978-981-13-3317-0_62

11. Dharek, M.S., Sreekeshava, K.S., Vengala, J., Pramod, K., Sunagar, P., Shivaprakash, M.V. (2022). Experimental Investigations on Utilization of Bagasse Ash in Adobe Bricks. In: Nandagiri, L., Narasimhan, M.C., Marathe, S., Dinesh, S. (eds) Sustainability Trends and Challenges in Civil Engineering. Lecture Notes in Civil Engineering, vol 162. Springer, Singapore. https://doi.org/10.1007/978-981-16-2826-9_31
12. Dharek, M.S., Sunagar, P., Harish, K., Sreekeshava, K.S., Naveen, S.U., Bhanutej (2020). Performance of Self-flowing Concrete Incorporated with Alumina Silicates Subjected to Elevated Temperature. In: Subramaniam, K., Khan, M. (eds) Advances in Structural Engineering. Lecture Notes in Civil Engineering, vol 74. Springer, Singapore. https://doi.org/10.1007/978-981-15-4079-0_10
13. Dharek, M.S. et al. (2021). Experimental Investigations on Strength Performance of the Brick Produced by Blending Demolished Waste with Pozzolanic Materials. In: Biswas, S., Metya, S., Kumar, S., Samui, P. (eds) Advances in Sustainable Construction Materials. Lecture Notes in Civil Engineering, vol 124. Springer, Singapore. https://doi.org/10.1007/978-981-33-4590-4_54
14. Bagherzadeh, R., Sadeghi, A., & Latifi, M. (2012). Utilizing polypropylene fibers to improve physical and mechanical properties of concrete. Textile Research Journal, 82, 88 - 96. https://doi.org/10.1177/0040517511420767
15. Broda, J., & Brachaczek, W. (2015). Influence of Polypropylene Fibre Geometry on the Mechanical Properties of Cement Mortars. Fibres & Textiles in Eastern Europe.
16. Gullì, G., Palamara, D., Bruzzaniti, P., Bertino, R., Grungo, F., & Calabrese, L. (2022). Flexural Toughening of a Cementitious Mortar Reinforced with Wave-Shaped Short Plastic Fibers. JOM, 75, 537-548. https://doi.org/10.1007/s11837-022-05623-3
17. Hrabová, K., Láník, J., & Lehner, P. (2025). Study of Mechanical and Fracture Properties of Concrete with Different Lengths of Polypropylene Fibers. Buildings. https://doi.org/10.3390/buildings15173041
18. Li, L., Chu, S., Zeng, K., Zhu, J., & Kwan, A. (2018). Roles of water film thickness and fibre factor in workability of polypropylene fibre reinforced mortar. Cement and Concrete Composites. https://doi.org/10.1016/j.cemconcomp.2018.07.014
19. Mehdipour, I., Vahdani, M., Libre, N., & Shekarchi, M. (2013). Relationship between workability and mechanical properties of fibre-reinforced self-consolidating mortar. Magazine of Concrete Research, 65, 1011-1022. https://doi.org/10.1680/macr.12.00088
20. Noushini, A., Hastings, M., Castel, A., & Aslani, F. (2018). Mechanical and flexural performance of synthetic fibre reinforced geopolymer concrete. Construction and Building Materials. https://doi.org/10.1016/j.conbuildmat.2018.07.110
21. Si, W., Cao, M., & Li, L. (2020). Establishment of fiber factor for rheological and mechanical performance of polyvinyl alcohol (PVA) fiber reinforced mortar. Construction and Building Materials, 265, 120347. https://doi.org/10.1016/j.conbuildmat.2020.120347
22. Silva, E., Coelho, J., & Bordado, J. (2013). Strength improvement of mortar composites reinforced with newly hybrid-blended fibres: Influence of fibres geometry and morphology. Construction and Building Materials, 40, 473-480. https://doi.org/10.1016/j.conbuildmat.2012.11.017
23. Topçu, B., Demirel, O., & Uygunoğlu, T. (2017). Physical and Mechanical Properties of Polypropylene Fiber Reinforced Mortars. **.
24. Wang, T., Fan, X., Gao, C., Qu, C., Liu, J., & Yu, G. (2023). The Influence of Fiber on the Mechanical Properties of Geopolymer Concrete: A Review. Polymers, 15. https://doi.org/10.3390/polym15040827