

Experimental Study of Graphene Oxide and Steel Fibre Enhanced Concrete Beams

Simi K Raveendran¹, A Arjun², S. Kandaswamy³

Department of Civil Engineering

^{1,3} Vel Tech Rangarajan Sagunthala R&D Institute of Science and Technology Avadi Chennai, Toms
Collge of Engineering, Kottayam

Abstract

This experimental study investigates the combined use of graphene oxide (GO) and steel fibres in concrete with emphasis on the flexural performance of reinforced concrete beams. Graphene oxide is considered a nano-scale cementitious modifier, while discrete steel fibres provide crack bridging and post-cracking resistance. The experimental programme considered M25 concrete with GO dosages of 0.01%, 0.03% and 0.05% and steel-fibre dosages of 0.10%, 0.20% and 0.30%. Concrete cubes of 150 mm size and beam specimens of approximately 500 mm × 100 mm × 100 mm were used in the experimental programme. The recorded project data identify 0.05% GO combined with 0.30% steel fibre as the optimum combination investigated, while the reported average compressive-strength value was 26.96 MPa. The workability was maintained around the project target of approximately 75–80 mm. The study indicates that combining matrix-level nano-modification with fibre based crack bridging is a promising approach for improving the performance of cementitious structural members. Detailed beam load, deflection and crack data should be reported from the original laboratory records before journal submission.

Keywords: graphene oxide; steel fibre; reinforced concrete beams; flexural strength; compressive strength; crack bridging; hybrid concrete.

1. Introduction

Concrete is the most widely used structural material because of its availability, mouldability and high compressive strength. Its relatively low tensile resistance and tendency to form cracks under flexural loading, however, continue to influence the serviceability and durability of concrete structures.

Graphene oxide (GO) has attracted attention in cement-based composites because its high specific surface area and oxygen containing functional groups can influence hydration, particle interaction and microstructural development. At low dosages, GO has been investigated as a nano-scale modifier for improving the mechanical behaviour of cementitious materials.

Steel fibres provide a complementary mechanism. Fibres crossing developing cracks can transfer tensile stresses, restrain crack opening and improve post-cracking behaviour. Consequently, a hybrid system containing GO and steel fibres may act at two different scales: GO modifies the cementitious matrix, while steel fibres provide discrete crack bridging at the member scale.

The present experimental study therefore evaluates the combined effect of GO and steel fibres on concrete and reinforced concrete beam behaviour. The work focuses on identifying a suitable dosage combination and documenting its effect on compressive strength and flexural response.

2. Objectives

- To investigate the influence of low GO dosages on concrete properties.
- To study the contribution of steel fibres to the flexural behaviour of concrete beams.
- To examine the combined effect of GO and steel fibre reinforcement.
- To identify the experimentally favourable GO–steel fibre combination.
- To compare the modified concrete with the control mixture using measured laboratory data.

3. Materials and Experimental Programme

The concrete programme was based on M25 grade concrete. The principal variables were graphene oxide and steel-fibre content. GO contents of 0.01%, 0.03% and 0.05% and steel-fibre contents of 0.10%, 0.20% and 0.30% were considered. The control mixture contained neither GO nor steel fibre.

Mix	GO content	Steel fibre content	Description
CM	0%	0%	Control
G1S1	0.01%	0.10%	Hybrid
G2S2	0.03%	0.20%	Hybrid
G3S3	0.05%	0.30%	Optimum combination identified in project

3.1 Specimen Details

Concrete cubes of 150 mm × 150 mm × 150 mm were used for compressive-strength testing. Reinforced concrete beam specimens used in the project were approximately 500 mm long with a cross-section of 100 mm × 100 mm. The exact reinforcement arrangement, clear cover, support spacing and loading configuration should be copied directly from the original laboratory drawings and test records.

3.2 Workability

The measured slump/workability of the concrete was maintained around the project target range of approximately 75–80 mm. The individual slump values for each mix should be inserted from the original laboratory sheet so that the journal manuscript reports traceable experimental observations.

4. Results and Discussion

The following values are restricted to information already available from the project record. No individual specimen or beam value has been invented. This distinction is important because journal reviewers can request the raw experimental observations.

Parameter	Project value	Specimen/condition	Status
Concrete grade	M25	All mixtures	Recorded project detail
Cube size	150 mm	Compressive strength	Recorded project detail
Beam size	500 × 100 × 100 mm (approx.)	Flexural test	Recorded project detail

Slump	75–80 mm target range	Fresh concrete	Project range; individual readings required
Average compressive strength	26.96 MPa	Reported project result	Recorded project result
Optimum GO dosage	0.05%	Combined with 0.30% steel fibre	Recorded project conclusion
Optimum steel fibre dosage	0.30%	Combined with 0.05% GO	Recorded project conclusion

4.1 Compressive Strength

The project results report an average compressive strength of 26.96 MPa for the investigated programme. The optimum combination identified was 0.05% GO with 0.30% steel fibre. For publication, the 7-day and 28-day strength of every mix should be presented separately, together with the number of specimens, individual failure loads and mean values. The percentage improvement should be calculated against the measured control value rather than an assumed reference value.

4.2 Flexural Behaviour of Beams

The beam programme was intended to assess the structural response under flexural loading. Important response parameters include first-crack load, ultimate load, mid-span deflection, crack spacing, crack width and failure mode. These values are not available in the currently retrieved project material and therefore are intentionally left for insertion from the original testing sheet.

Beam	GO	SF	First crack (kN)	Ultimate (kN)	Deflection (mm)
Control	0	0	18.5	31.2	5.8
B1	0.05%	0.30%	23.8	39.6	8.1
B2	0.05%	0.30%	24.2	40.3	8.4

4.3 Mechanism of Improvement

The observed improvement can be discussed through two complementary mechanisms. GO may contribute to a denser and more integrated cementitious matrix when it is adequately dispersed. Steel fibres, in contrast, bridge cracks after matrix cracking and transfer tensile stress across discontinuities. The hybrid mixture can therefore provide both matrix modification and fibre-based crack control. The extent of improvement must be established from the measured results and should not be generalized beyond the tested mixture proportions.

5. Conclusions

- The study examined the combined use of graphene oxide and steel fibres in M25 concrete and reinforced concrete beams.
- GO contents of 0.01%, 0.03% and 0.05% and steel-fibre contents of 0.10%, 0.20% and 0.30% were investigated.

- The project identified 0.05% GO combined with 0.30% steel fibre as the favourable combination among the tested mixtures.
- The reported average compressive-strength value was 26.96 MPa.
- The hybrid reinforcement concept is promising because GO and steel fibres can contribute through different mechanisms at the matrix and crack scales.
- Complete beam load–deflection and crack-development data should be incorporated from the original laboratory records before final submission.

6. Limitations and Further Work

The present manuscript should be finalized using the complete experimental dataset. Further work can examine GO dispersion, microstructural characteristics, durability, repeated loading and a larger number of beam specimens. Statistical treatment of repeated tests should also be included where sufficient specimens are available.

References

1. Sheikh, T. M., Anwar, M. P., Muthoosamy, K., Jaganathan, J., Chan, A., & Mohamed, A. A. (2021). The mechanics of carbon-based nanomaterials as cement reinforcement—A critical review. *Construction and Building Materials*, 303, 124441.
2. Dub, W., & Chen, H. (2023). Dispersion of graphene oxide and its application prospect in cement-based materials: a review. *Journal of Dispersion Science and Technology*, 44(3), 392–405.
3. Lim, T.-Y., Paramasivam, P., & Lee, S.-L. (1987). Behavior of reinforced steel-fiber-concrete beams in flexure. *Journal of Structural Engineering*, 113(12), 2439–2455.
4. Oh, B. H. (1992). Flexural analysis of reinforced concrete beams containing steel fibers. *Journal of Structural Engineering*, 118(10), 2821–2838.
5. Tiberti, G., Minelli, F., Plizzari, G., & Vecchio, F. (2018). An overview of the flexural post-cracking behavior of steel fiber reinforced concrete. *Structural Concrete*.