

Performance Assessment of Graphene-Enhanced M30 Concrete for Sustainable and Durable Structural Application

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Abstract: Concrete is one of the most widely used construction materials owing to its high compressive strength, affordability, and versatility. Nevertheless, its inherent limitations, including low tensile strength, brittleness, susceptibility to cracking, and permeability, restrict its long-term durability and structural efficiency. The present study investigates the influence of graphene incorporation on the mechanical and durability characteristics of M30 grade concrete intended for structural applications. Five concrete mixtures were prepared comprising a control mix and graphene dosages of 1.0, 3.0, 5.0, and 7.0 g/m³. Concrete specimens were cast and cured under standard conditions, and their compressive strength, split tensile strength, flexural strength, and water absorption characteristics were evaluated after 28 days of curing in accordance with relevant Indian Standard procedures. The experimental findings revealed that graphene significantly enhanced the overall performance of concrete up to an optimum dosage. Compared with the control mix, the incorporation of 5.0 g/m³ graphene (G3) produced the highest compressive strength (41.56 MPa), split tensile strength (3.58 MPa), and flexural strength (5.11 MPa), representing improvements of 18.07%, 27.40%, and 21.09%, respectively. Simultaneously, the G3 mix exhibited the lowest water absorption value (1.64%), corresponding to a 33.87% reduction relative to conventional concrete. However, a slight decline in performance was observed at 7.0 g/m³ graphene dosage, which was attributed to particle agglomeration and non-uniform dispersion. The improvements were associated with graphene-induced matrix densification, pore refinement, enhanced hydration, and crack-bridging mechanisms. The study concludes that graphene is an effective nano-reinforcement material for developing high-strength, durable, and sustainable concrete, with an optimum dosage of 5.0 g/m³ recommended for structural applications.

Keywords: Graphene, M30 Concrete, Compressive Strength, Split Tensile Strength, Flexural Strength, Water Absorption, Durability, Structural Applications.

INTRODUCTION

Concrete remains the most extensively utilized construction material worldwide because of its availability, cost-effectiveness, and excellent compressive strength. However, conventional concrete exhibits inherent limitations such as low tensile strength, brittleness, susceptibility to cracking, permeability, and long-term durability concerns. These deficiencies often lead to increased maintenance costs and reduced service life of structures. Consequently, researchers have increasingly focused on advanced nanomaterials capable of enhancing the mechanical and durability characteristics of cementitious composites. Among these materials, graphene and its derivatives, including graphene oxide (GO) and graphene nanoplatelets (GNP), have emerged as highly promising additives owing to their extraordinary mechanical properties, high specific surface area, superior thermal conductivity, and exceptional interfacial bonding capabilities.

Recent investigations have demonstrated that graphene incorporation can substantially improve the structural performance of concrete. Kalif et al. (2026) reported that graphene-modified concrete containing an optimum dosage of 0.4% by cement mass achieved compressive strengths of 25.16 N/mm² and 37.75 N/mm² at 7 and 28 days, respectively, along with enhanced flexural strength and reduced water permeability. Similarly, Mohammad et al. (2026) emphasized that GO and GNP refine cementitious microstructures through nucleation effects, crack bridging, and improved interfacial bonding, thereby enhancing compressive, tensile, and flexural performance when applied within optimal dosage limits.

The synergistic potential of multi-scale reinforcement has also attracted considerable attention. Lu et al. (2026) demonstrated that hybrid incorporation of graphene and carbon fibers significantly improved compressive strength, splitting tensile strength, and impact resistance through nano-filling and enhanced fiber-matrix interactions. Furthermore, graphene has shown substantial promise in improving the durability of concrete under aggressive environments. Srivastava and Bansal (2026) reported that graphene oxide-based concrete composites exhibited delayed corrosion initiation, reduced mass loss, and improved corrosion resistance compared with conventional concrete.

Graphene modification has also been associated with enhanced impermeability and thermal performance. Shang et al. (2025) observed that graphene reduced brittleness, increased density, improved thermal conductivity, and lowered penetration depth, thereby contributing to improved durability. Likewise, Ren et al. (2025) highlighted the effectiveness of graphene-coated phase change materials in producing high-performance thermal energy storage concrete with excellent mechanical characteristics.

Comprehensive reviews by Wei et al. (2024) further summarized that graphene-modified cementitious composites possess superior fresh, mechanical, durability, and multifunctional properties, although challenges related to dispersion, cost, and large-scale implementation remain. Experimental studies by Kaushik et al. (2024) and Sheng et al. (2023) also confirmed that appropriate graphene dosages significantly improve compressive, tensile, and flexural strengths through accelerated hydration, filler effects, and microstructural refinement. However, excessive graphene contents frequently result in agglomeration, reducing the anticipated benefits.

Earlier investigations by Zhao et al. (2020) and Pershin et al. (2019) additionally demonstrated improvements in crack resistance, microhardness, shrinkage reduction, and water absorption characteristics of graphene-enhanced cementitious materials. Despite these encouraging findings, variations in graphene dosage, dispersion techniques, and concrete grades have resulted in inconsistent recommendations regarding optimum graphene content.

Therefore, further experimental investigations are necessary to evaluate the influence of graphene on conventional structural concrete grades and to identify dosage levels that maximize mechanical strength and durability. Such studies will contribute to the development of high-performance, sustainable, and long-lasting concrete suitable for modern structural applications.

II. REVIEWS AND FINDINGS

Author(s)	Year	Material/Focus	Key Findings
Kalif et al.	2026	Graphene concrete	Optimum 0.4% graphene improved 28-day compressive strength to 37.75 N/mm ² , flexural strength to 4.47 N/mm ² , and reduced permeability.
Mohammad et al.	2026	GO and GNP in OPC/AAB concrete	GO and GNP enhanced microstructure, crack bridging, and strength; excessive dosage caused agglomeration.
Lu et al.	2026	Graphene-carbon fiber concrete	Hybrid reinforcement increased compressive strength by 23.03%, tensile strength by 32.84%, and impact resistance by 49.71%.
Srivastava and Bansal	2026	GO concrete composites	0.03% GO improved compressive strength and delayed corrosion-induced cracking by 22 days.
Shang et al.	2025	Graphene concrete	Compressive strength increased by 44%; permeability and penetration depth were significantly reduced.
Ren et al.	2025	Graphene-based thermal concrete	Graphene-coated PCM improved thermal storage and maintained compressive strength up to 73.1 MPa.
Wei et al.	2024	Review of graphene cement composites	Reported improvements in mechanical properties and durability, while highlighting dispersion and cost challenges.
Kaushik et al.	2024	GO with different aggregates	Improved compressive, tensile, and flexural strengths due to enhanced aggregate-matrix bonding.
Sheng et al.	2023	Graphene mortar	Optimum 0.03% graphene increased 28-day compressive and flexural strengths by 33.99% and 27.18%, respectively.
Zhang et al.	2023	Graphene-modified epoxy	Enhanced tensile, compressive, flexural strengths and fracture toughness; improved durability under alkaline exposure.
Sharma et al.	2022	GO/CNT epoxy coatings	0.4 wt.% GO improved corrosion resistance of reinforced concrete structures.
Shang et al.	2021	Graphene epoxy-coated rebars	Improved anti-corrosion performance, although bond strength remained lower than uncoated bars.
Zhang et al.	2021	GNP concrete under climate effects	Reduced carbonation depth by 10–30% under varying environmental conditions.
Zhao et al.	2020	Graphene cement composites	Optimum 0.06 wt.% graphene improved compressive and flexural strengths by approximately 10% and reduced shrinkage by 30%.
Pershin et al.	2019	Graphene-modified concrete	0.05 wt.% graphene increased bending strength by 50% and reduced water absorption threefold.

III. RESEARCH METHODOLOGY FOR EXPERIMENTAL RESULTS

The present experimental investigation was conducted to evaluate the effect of graphene incorporation on the mechanical and durability properties of M30 grade concrete. Ordinary Portland Cement (OPC), fine aggregate, coarse aggregate, water, and superplasticizer were used to prepare the control and graphene-modified concrete mixes. Five different concrete mixtures were designed, comprising one control mix without graphene (0.0 g/m³) and four graphene-modified mixes containing 1.0 g/m³ (G1), 3.0 g/m³ (G2), 5.0 g/m³ (G3), and 7.0 g/m³ (G4) of graphene. Concrete specimens were cast according to relevant Indian Standard specifications and cured under normal water-curing conditions for 28 days. Cube specimens (150 mm × 150 mm × 150 mm) were prepared for compressive strength testing, cylindrical specimens (150 mm × 300 mm) for split tensile strength evaluation, and prism specimens (100 mm × 100 mm × 500 mm) for flexural strength determination. Water absorption tests were also conducted to assess

the durability characteristics of the developed concrete mixes. The compressive strength test was performed using a Compression Testing Machine (CTM) in accordance with IS 516 provisions. Split tensile strength was evaluated using the indirect tensile test method on cylindrical specimens, while flexural strength was determined using the two-point loading method. Water absorption was measured by recording the percentage increase in specimen weight after immersion and oven drying.

IV. RESULT AND DISCUSSION

The experimental results obtained from the investigation of graphene-modified M30 concrete and discusses the influence of varying graphene dosages on its mechanical and durability characteristics. The performance of five concrete mixtures, comprising one control mix and four graphene-incorporated mixes, was evaluated through compressive strength, split tensile strength, flexural strength, and water absorption tests conducted after the specified curing period. The results are analyzed systematically to identify trends in strength development and durability enhancement resulting from graphene incorporation.

Table: Estimation of Performance

Mix	Graphene (g/m ³)	28-Day Compressive Strength (MPa)	28-Day Split Tensile Strength (MPa)	28-Day Flexural Strength (MPa)	Water Absorption (%)	Overall Performance
Control	0.0	35.20	2.81	4.22	2.48	Baseline
G1	1.0	37.16	3.04	4.58	2.21	Improved
G2	3.0	39.36	3.27	4.80	1.94	Good
G3	5.0	41.56	3.58	5.11	1.64	Optimum Performance
G4	7.0	40.08	3.42	4.88	1.79	Slight Decline

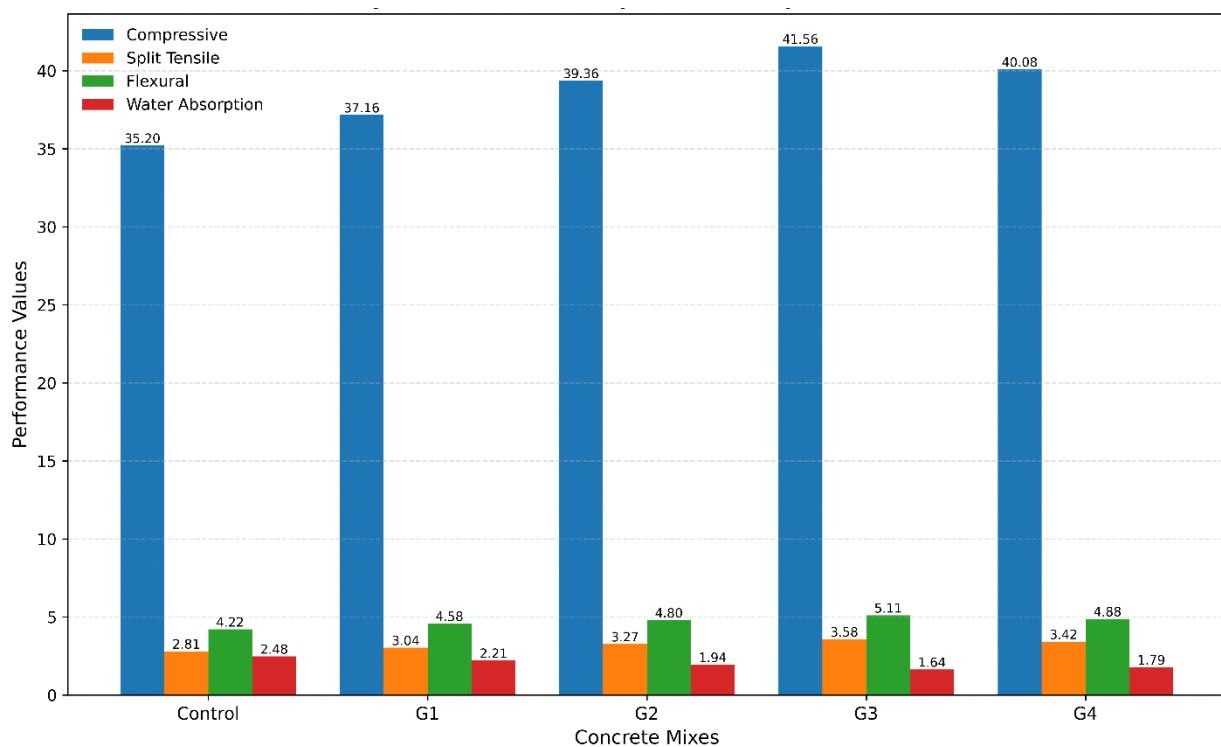


Fig 1: Estimation of Performance

The experimental results as presented in above table and figure obtained after 28 days revealed that graphene significantly enhanced the performance of concrete up to an optimum dosage. The control mix exhibited compressive strength, split tensile strength, flexural strength, and water absorption values of 35.20 MPa, 2.81 MPa, 4.22 MPa, and 2.48%, respectively. Progressive improvements were observed in mixes G1 and G2. Among all mixtures, the G3 mix containing 5.0 g/m³ graphene demonstrated the best overall performance, achieving the highest compressive strength (41.56 MPa), split tensile strength (3.58 MPa), and flexural strength (5.11 MPa), together with the lowest water absorption value (1.64%). However, a slight reduction in performance was observed in G4

(7.0 g/m³ graphene), which may be attributed to graphene agglomeration and non-uniform dispersion at higher dosages. The G3 mix containing 5.0 g/m³ graphene demonstrated the best overall performance, exhibiting the highest mechanical strengths and the lowest water absorption, confirming it as the optimum graphene dosage for M30 concrete. The findings confirmed that graphene acts as an effective nano-reinforcement material by improving matrix densification, refining pore structure, and enhancing crack-bridging mechanisms. Therefore, an optimum graphene dosage of 5.0 g/m³ was identified for producing high-strength, durable, and sustainable M30 concrete suitable for structural applications.

V. CONCLUSION

The present investigation evaluated the effectiveness of graphene as a nano-reinforcement material for enhancing the mechanical and durability performance of M30 grade concrete. The experimental results demonstrated that graphene incorporation substantially improved the compressive strength, split tensile strength, flexural strength, and impermeability characteristics of concrete when used in appropriate dosages. Among the five concrete mixtures investigated, the G3 mix containing 5.0 g/m³ graphene exhibited the optimum performance. This mixture achieved a compressive strength of 41.56 MPa, split tensile strength of 3.58 MPa, and flexural strength of 5.11 MPa after 28 days of curing, surpassing the control concrete by 18.07%, 27.40%, and 21.09%, respectively. In addition, the same mix recorded the minimum water absorption value of 1.64%, indicating a 33.87% improvement in impermeability and durability compared with conventional concrete. The observed enhancements can be attributed to the nano-filler effect of graphene, refinement of the pore structure, acceleration of cement hydration, improved interfacial bonding, and effective crack-bridging action within the concrete matrix. These mechanisms contributed to increased matrix compactness and improved resistance to crack propagation. However, the slight reduction in performance observed in the G4 mix (7.0 g/m³ graphene) suggests that excessive graphene content may lead to agglomeration and poor dispersion, thereby diminishing its reinforcing efficiency. Overall, the findings confirm that graphene possesses significant potential for producing advanced cementitious composites with superior structural performance and durability. The optimum graphene dosage of 5.0 g/m³ is recommended for M30 concrete applications, offering a promising pathway toward the development of high-performance, sustainable, and long-lasting construction materials suitable for modern infrastructure systems.

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