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Development Of Sustainable Photocatalytic Cement Mortar Using g-C₃N₄ And Recycled Glass Powder

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Abstract—The construction industry has high resource consumption and associated emissions, creating a need for sustainable building materials. This study investigates a photocatalytic cement mortar incorporating graphitic carbon nitride (g-C₃N₄) and recycled glass powder. The visible-light photocatalytic capability of g-C₃N₄ offers potential for pollutant degradation, while recycled glass powder provides a route for waste utilization and may contribute to mortar performance. Control mortar (CM) and three sustainable photocatalytic glass mortars (SPGM 1–3) were prepared with different g-C₃N₄ and glass powder contents. Compressive and flexural strengths were evaluated after 3, 7, and 28 days of curing. The results show that SPGM 1, containing 0.5% g-C₃N₄ and 5% glass powder by cement mass, achieved the highest 28-day compressive strength of 55.60 N/mm² and flexural strength of 8.80 N/mm² among the tested mixtures.

Index Terms—g-C₃N₄, recycled glass powder, photocatalytic mortar, compressive strength, flexural strength, sustainable construction.

I. Introduction

The issue of environmental pollution has become a major global concern, particularly in urban settings. Air pollutants such as nitrogen oxides (NO_x) and volatile organic compounds (VOCs) contribute to poor air quality and environmental degradation. Photocatalytic building materials provide an approach for reducing pollutants while also offering functional surface properties.

Graphitic carbon nitride (g-C₃N₄) is a polymeric semiconductor with photocatalytic activity under visible light. Its relatively favorable optical response, stability, and compatibility with cementitious matrices make it a potential photocatalyst for sustainable construction materials. Compared with conventional photocatalysts such as TiO₂, g-C₃N₄ offers the potential for greater utilization of visible-light irradiation.

Recycled glass powder can also be incorporated into cementitious materials as a waste-derived supplementary component. Its pozzolanic behavior can contribute to the formation of additional calcium silicate hydrate (C-S-H), while its use can reduce the quantity of waste glass sent to landfills and support resource conservation.

Therefore, this study combines g-C₃N₄ with recycled glass powder in cement mortar and evaluates the resulting mechanical performance. The investigation focuses on compressive and flexural strengths at 3, 7, and 28 days for different g-C₃N₄ and glass powder proportions.

II. Literature Review

Photocatalysis has been investigated for self-cleaning and air-purification applications in cement-based materials. TiO₂ is one of the most widely studied photocatalysts; however, its performance can be affected by aggregation in cementitious mixtures and its strong dependence on ultraviolet irradiation. g-C₃N₄ has therefore attracted attention because of its visible-light photocatalytic response and suitable electronic structure.

Previous studies have investigated photocatalytic cementitious materials using TiO₂-based systems, g-C₃N₄ composites, and layered double hydroxides. Lu et al. reported photocatalytic cement mortar incorporating g-C₃N₄/CoAl-LDH nanoflowers and examined its mechanical and microstructural characteristics. Other studies have explored Ti-Zn-Al nanocomposites and photocatalytic technologies for pollutant degradation. These studies indicate the potential of photocatalytic cementitious materials for environmental applications, while also highlighting the need to optimize photocatalyst content and mixture composition.

III. Materials and Methods

Portland cement was used as the principal binder, and fine aggregate was used as the sand component. Recycled glass powder was used as a waste-derived material, while g-C₃N₄ was incorporated as the photocatalytic additive. The mortar specimens were prepared using a water-to-cement ratio of 0.5 and a cement-to-sand ratio of 1:3 by mass.

3.1 Mix Proportions

Four mortar mixtures were investigated. The g-C₃N₄ and glass powder contents in SPGM 1, SPGM 2, and SPGM 3 correspond to

0.5%, 1.0%, and 1.5% g-C₃N₄ and 5%, 10%, and 15% glass powder, respectively, based on the cement mass.

Table 1: Proportion of Mixes

Mix	Cement (g)	Sand (g)	g-C ₃ N ₄ (g)	Glass powder (g)	Water (mL)
CM	400	1200	0	0	200
SPGM 1	380	1200	2	20	200
SPGM 2	360	1200	4	40	200
SPGM 3	340	1200	6	60	200

3.2 Specimen Preparation and Curing

Cement and sand were initially mixed in the dry state. The required g-C₃N₄ was dispersed ultrasonically in water for 10 min to obtain a more uniform suspension. The suspension was then added to the cement-sand mixture and mixed for 3 min at low speed followed by 2 min at high speed. The mortar was placed in 70.6 × 70.6 × 70.6 mm cube moulds and compacted in layers. The specimens were stored in moist air for 24 h, demoulded, and subsequently cured in fresh water. Testing was conducted after 3, 7, and 28 days.

3.3 Mechanical Strength Tests

Compressive and flexural strengths were used to evaluate the mechanical performance of the mortar. The compressive strength was determined from the maximum load at failure divided by the loaded cross-sectional area. Flexural strength was also evaluated for the specified curing ages. The results are reported in N/mm².

IV. Results and Discussion

Table 2 presents the compressive and flexural strength results obtained for the four mortar mixtures. The control mortar reached 54.30 N/mm² compressive strength and 8.00 N/mm² flexural strength at 28 days. SPGM 1 showed the highest values, reaching 55.60 N/mm² compressive strength and 8.80 N/mm² flexural strength at 28 days. SPGM 2 and SPGM 3 exhibited lower 28-day compressive strengths of 53.40 and 50.20 N/mm², respectively.

The results indicate that the lower additive level used in SPGM 1 provided the best mechanical performance among the investigated mixtures. Increasing the g-C₃N₄ content from 0.5% to 1.5% and the glass powder content from 5% to 15% did not produce a corresponding increase in strength. The reduction observed at the higher replacement levels suggests that the mixture proportions require optimization to balance the beneficial effects of the additives with the cementitious matrix.

Table 2: Compressive And Flexural Strength Results

Mix	g-C ₃ N ₄ (%)	Glass (%)	CS 3 d	CS 7 d	CS 28 d	FS 3 d	FS 7 d	FS 28 d
CM	0	0	52.3	53.3	54.3	6.6	7.4	8.0
SPGM 1	0.5	5	52.4	53.34	55.6	6.9	7.8	8.8
SPGM 2	1.0	10	51.4	51.2	53.4	6.8	7.6	8.4
SPGM 3	1.5	15	51.6	49.3	50.2	6.8	7.5	8.3

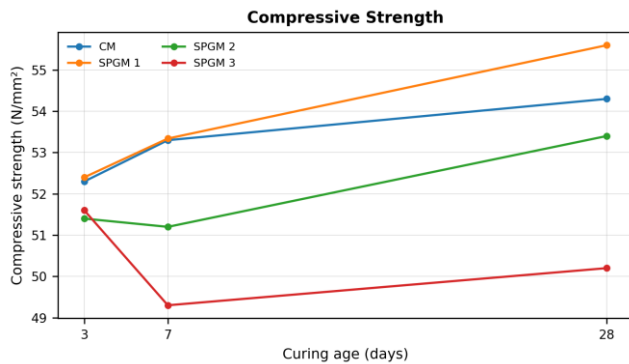


Figure 1. Compressive strength at different curing ages.

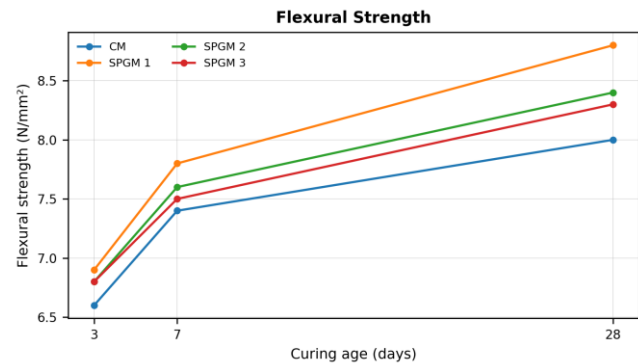


Figure 2. Flexural strength at different curing ages.

V. Conclusion

This study evaluated cement mortar containing different proportions of g-C₃N₄ and recycled glass powder. The mechanical results demonstrate that the mixture composition strongly influences mortar strength.

Among the investigated mixtures, SPGM 1, containing 0.5% g-C₃N₄ and 5% glass powder by cement mass, achieved the highest 28-day compressive strength (55.60 N/mm²) and flexural strength (8.80 N/mm²). Higher additive contents in SPGM 2 and SPGM 3 resulted in lower compressive strength compared with SPGM 1.

The results support the potential of combining g-C₃N₄ with recycled glass powder in sustainable cement mortar, while also demonstrating the importance of optimizing additive proportions. Further work should evaluate photocatalytic pollutant degradation and durability alongside mechanical performance.

VI. References

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