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DEVELOPING SUSTAINABLE PHOTOCATALYTIC CEMENT MORTAR THROUGH G-C_3N_4 INTEGRATION

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Abstract: Since the construction industry has high emission rates and resource demanding rate, whose effect on the environment is tremendous in a destructive sense, there is need of sustainable building materials. One of the potential options to reduce air pollution and promote self-cleaning materials is adding photocatalytic component to cementitious ones. The photocatalytic capabilities, affordability, and durability of graphitic carbon nitride (g-C_3N_4) under visible light makes the breakdown of airborne contaminants possible, as it is a polymeric semiconductor that has gained attention towards its use as building materials. Moreover, in addition to the sustainability of the material, the use of glass powder as an additional cementitious component created through recovered waste glass enhances the durability and the mechanical properties of the material by reducing waste. Photocatalytic mortar is manufactured out of glass powder and g-C3N4 and it fits in low-light urban conditions as it removes pollutants and enhances the performance of materials. The study ascertains the potential of the materials through examination of the mechanical and environmental properties of the hybrid materials to be applied in sustainable building applications

Index Terms - Glass Powder, g-C_3N_4, Mortar, Strength.

I. INTRODUCTION

The issue of environmental pollution has become a major global issue particularly in the urban settings. Air pollution, in form of automobile emissions and industrial waste products, causes smog, acid rain and poor environment, thus causing air pollution. These are aspects that threaten human health and destroy ecosystems. As well as affecting air quality, nitrogen oxides (NOx) and volatile organic compounds (VOCs) also lead to poor quality of fine particulate matter and ground-level ozone, both of which damage respiratory illnesses and become temperature-rising agents. In order to overcome these pitfalls, there are some imaginative methods to reduce the level of pollution and its adverse consequences on the ecosystem that is being sought. One of the most promising ways to do it is to add graphitic carbon nitride (g-C_3N_4) which is a substance with photocatalytic activity. Besides light absorption, particularly the UV and visible light, g-C_3N_4 has the potential to accelerate chemical reactions to transform, among others pollutants, nitrogen oxides and volatile organic compounds (VOCs) into less harmful products such as carbon dioxide and nitrates. Cement mortar is an eco-product to construct structures in the city as g-C3N4 addition will significantly improve mortar properties to tell themselves and reduce air pollution. Photocatalytic activity in g-C_3N_4 exposed to light allows the mortar to react with the environment, which brings benefits such as clean surfaces and air and the decrease in the heat islands in urban areas. Also, g-C_3N_4 is a superior choice in improving the environmental behavior section of building materials in green construction and intelligent cities on account of stability and its compatibility with cement matrices.

Graphitic carbon nitride (g-C_3N_4) has many structural and electronic advantages over other photocatalytic materials like TiO2 and ZnO. Most importantly, g-C_3N_4 has a visible light photocatalytic activity that makes it particularly effective in natural sunlight, as opposed to TiO2 and ZnO photocatalytic activity that is strong at ultraviolet radiation. For this reason, g-C3N4 is more practically applied in urban and outdoor applications, whereas TiO2 and ZnO have very limited deployment scenarios. Some additional important features are that g-C_3N_4 is non-toxic; it is considered, safe and sustainable; it has very low degradation rates and a high level of stability (environmentally). The g-C3N4 is very inexpensive; it is easy to integrate within cementitious matrices without loss in mechanical properties; it is much cheaper and easier to process as well compared to many other nucleophiles or coordination complexes that may require more elaborate and time-consuming synthesis or modifications.

In addition, g-C_3N_4 is very effective at breaking down harmful nitrogen oxides (NO_x) and volatile organic compounds (VOCs) and improving air quality while providing the ability to self-clean surfaces. Accordingly, g-C3N4 is a desirable component to consider in sustainable building materials that decrease urban air pollution, reduced maintenance costs and provide long-term functional and environmental benefits.

There are further practical benefits to using recycled glass in place of some cement when building. The strength and durability of the mortar are improved when the pozzolanic qualities of glass powder mix with the calcium hydroxide in cement to create more calcium silicate hydrates (C-S-H). Compressive strength and chemical resistance to sulfate assaults are two examples of how this enhances mechanical performance. By using recycled glass, a more sustainable and long-lasting building material may be produced, lowering the demand for natural resources and advancing the circular economy. However, issues with glass content and mix design optimization persist due to high content.

There are even additional practical advantages of using recycled glass instead of part of the cement in construction. The original bonding agent in the mortar will be a stronger and better performing material due to the properties of pozzolans in the glass powder when mixed with calcium hydroxide in cement will create more calcium silicate hydrates (C-S-H). The mechanical performance of the mortar is improved through compressive strength and chemical resistance to sulfates. Utilizing recycled glass will create a better sustainable material while producing building material that has the potential for even greater durability and aid in the reduction of non-renewable resource consumption and help drive the local circular economy. However, there are still limitations we are facing with the glass content and the optimization of the mix design concerning the high.

Glass powder may also impact workability and future performance so more study is needed to ensure the right balance between these attributes is achieved. An exciting and sustainable way of using up resources in construction in an urban setting is by integrating graphitic carbon nitride (g-C_3N_4), or recovered glass powder for that matter, into photocatalytic cement mortar. This approach is able to advance a range of environmental problems by enhancing the mortar's potential to both reduce air pollution and increase waste recycling. The very well documented or well-known, g-C_3N_4 can photocatalytically decompose harmful pollutants, such as nitrogen oxides (NO_x) or volatile organic compounds (VOCs), into harmless non-harmful materials like harmless gases, under natural sunlight. In this way air quality is improved and along with viable benefits of achieving more durable urban buildings, this helps create cleaner urban living environments. By substituting part of the cement with recycled glass powder helps to ensure waste glass stays out of landfills, decreases CO2 emissions, and reduces the ecological impacts of cement production. Together, these two components improve the mechanical strength of the mortar, the durability of the mortar, and their ability to absorb pollutants and self-purify, and make it a greener and more energy efficient building material that meets modern building standards.

II. LITERATURE REVIEW

Nitrogen oxide emissions, which result in air pollution and soil eutrophication, are the two most serious environmental issues attributed to the accelerated industrialization of modern existence. These issues also have major ramifications for ecosystems and human health [1]. Regardless, cement, the most significant component of construction, is becoming increasingly scrutinized under the environmental spotlight [2]. Photocatalysis can help provide self-cleaning properties that enable structure's that may withstand sunshine and require little or no maintenance. Photocatalytic materials utilize semiconductors and generate reactive oxygen species that are critical when decontaminating air contaminants [3].

Professionally of photocatalysis, titanium dioxide (TiO2) has been used in a number of applications, including photocatalysis, catalysis, and antibacterial applications, for citizens safety and inertness, improving quality of lives [4]. However, TiO2 presents challenges with civil engineering processes because its tendency to aggregate when incorporated into mixtures with cement [5], and TiO2 shows reduced photocatalytic capability in the alkaline conditions of cementitious systems [6]. It is also important to point out that TiO2 requires UV light activation while it is certainly possible to utilize different photocatalysts in cement-based products.

Graphitic carbon nitride (g-C_3N_4) has emerged as a promising alternative because of its large specific surface area and favorable energy band gap for photocatalytic applications [7]. However, g-C_3N_4 has been shown to have a major disadvantage of a high rate of recombination of photogenerated carriers [8,9,10,11]. To overcome these issues of recombination researchers have investigated the fate of hybridizing g-C_3N_4 with other semiconductors or photocatalysts such as TiO2, ZnO, SnO2, and layered double hydroxides (LDHs). With strong results to reduce carrier recombination and limit the negative effects of the cementitious environment on g-C_3N_4, viability of adding g-C_3N_4 to cement has been addressed for purposes of depollution [11].

A recent study [1] investigated the characteristics of photocatalytic cement mortar with g-C_3N_4/CoAl-LDH nanoflowers. The study focused on how the nanoflowers affected the cement mortar's mechanical properties and microstructure. The objective of the study specifically highlighted how the nanoflowers affected the photocatalytic activity and the structural strength of the mortar for environmental applications such as air purification and self-cleaning surfaces. The results of the study suggest that g-C_3N_4/CoAl-LDH nanoflowers can improve the properties of cement-based materials by allowing for a compromise between strength and environmental benefits. [2] Vulic et al. (2013) investigate the use of photocatalytic Ti–Zn–Al nanocomposites to enhance the properties of cementitious mortars. This study aims to increase the photocatalytic activity of the mortar, which could lead to functions such as air filtration and self-cleaning surfaces. The goal is to use these nanocomposites to increase the capability of the mortar to break down contaminants making it potentially useful material for green building.

In a review of photocatalytic materials and technology for air purification, [3] Ren et al. (2017) investigated the degradation of harmful air pollution by using a light activated minerals like ZnO and TiO_2 to degrade harmful air pollutants including nitrogen oxides (NOx) and volatile organic compounds (VOCs). In a review, they outline the photocatalytic process, where a light energy promotes the material to produce reactive oxygen species which degrades the pollutants. The authors also reviewed alternative mechanisms that utilize these materials which coats or photocatalytic air purifiers for cleaning indoor air. While there is potential for the technologies, the authors highlight existing issues including materials stability and low visible light efficiency and offered suggestions to improve the air filtration. [5] Wang et al. (2018) consider the impact of the incorporation of TiO_2 nanoparticle addition into cement at low temperature on the physical and mechanical properties of cement. Furthermore, this study argues that TiO_2 nanoparticles improve the compressive strength, durability, and freeze-thaw resistance of cement making it more appropriate for use in cold climatic regions. The researchers also consider the effects of TiO_2 nanoparticles on the microstructure of cement, such as hydration and pore shape. The results demonstrate that TiO_2 nanoparticles drastically improve the performance of cement for use in cold-weather applications, which is highly relevant to construction in cold-weather climates.

III. MATERIAL AND METHODS

Portland cement is the principal binding agent in the composition, as found in mortar. Fine aggregate is fine particles, usually sand, in the case of mortar, concrete and other construction materials. Fine aggregate is necessary to enhance the bulk and workability of the mixture in mortar, and ultimately its strength and durability. Fine aggregates are classified by particle size, and the most common kind of fine aggregate is particle sizes that can pass through a 4.75 mm sieve. Recycled glass powder, an eco-friendly product, is made from reasonably sized post-consumer or industrial glass waste pulverized into fine powder. Recycled glass powder is typically used as a filler in paints and plastics, as well as in the manufacture of concrete, ceramics, and road materials. Incinerating glass waste into powder for recyclables reduces the consumption of raw materials and saves natural resources, while ultimately significantly reducing landfill waste. By using less energy than producing new glass, using recycled to glass powder reduces the adverse environmental effects of industrial processes. Graphitic carbon nitride is a polymeric material composed of carbon, nitrogen, and hydrogen atoms, arranged similar to graphite in layered patterned forms. The electrical characteristics of the polymer, such as it large surface area and capabilities to absorb visible light, drive its potential for photocatalysis.

3.1 Mix Proportions

The mix ratios will need to reflect the effect that these materials have on the cement hydration process, the workability and the final strength of the mortar. The glass powder is most often pozzolanic which means it can react with the calcium hydroxide (Ca (OH)2) released during the hydration of cement to form more calcium silicate hydrate (C-S-H) that will improve the strength and durability of the mortar. The g-C_3N_4 (assuming it is a nano-additive) can solely have a positive impact on properties such as early strength gain and microstructure densification. Mixing Ratios in Table 1.

Sl.No	Type	Cement (g)	Sand (g)	g-C_3N_4 (g)	Glass powder (g)	Water (ml)
1	CM	400	1200	0	0	200
2	SPGM 1	380	1200	2	20	200
3	SPGM 2	360	1200	4	40	200
4	SPGM 3	340	1200	6	60	200

Table 1: Proportion of Mixes

3.2 Preparation of Specimen

The compressive strength, flexural strength tests of the cement mortar are done by preparing the cube and by doing several tests. This test is carried out on the cube specimen of size 70.6 x 70.6 x 70.6mm. Metal moulds of cast iron are selected cleaned, and the inner layer of the specimen is applied with crude oil. The proposed cement mortar mix follows a water, cement, sand ratio of 0.5:1:3 by weight, where 1 part cement is combined with 3 parts sand. The mix also includes varying percentages of glass powder and g-C_3N_4 additive, both measured by the weight of cement. Glass powder is added at four different levels: 0%, 0.5%, 10%, and 15%, while g-C_3N_4 is incorporated at 0%, 0.5%, 1%, and 1.5%. Sand and cement are mixed in a dry state. A certain content of g-C_3N_4 powder was ultrasonically dispersed in water for 10min to obtain a uniformly dispersed suspension. Then the prepared g-C_3N_4 suspension was poured into the dry mixture of cement and sand and further mixed evenly for 3min at low speed and 2min at high speed. The detailed mix proportions are listed in table 1. A sonicator is used to mix g-C_3N_4 by applying ultrasonic waves, which help disperse and break down particles for a uniform mixture. The specimen is prepared as soon as practicable after mixing to produce fully compacted cement mortar. The concrete is filled into the mould in layers. Each layer is compacted by a tamping rod using equally spaced strokes distributed over the full section of the mould. The filled-up surface is finished smooth and level using a trowel. The test specimens are stored in moist air for 24 hours and after this period the specimens are removed from the moulds and kept submerged in clear fresh water until taken us prior to test. Curing is done in to 3days, 7 days, 28 days under ambient conditions.

3.3 Mechanical Strength of Cement Mortar

A significant means of establishing whether or not the cement mortar can endure compressive forces and failure was the compressive strength test. To establish the load bearing capacity of masonry and establish the stability and long-term performance of masonry, compressive strength of cement mortar is paramount. For the test, the mortars were cast as samples, normally cubes, with a mixture of cement, sand and water, the samples were cured for three, seven, and twenty-eight days to develop the required strength, following this period, the samples were tested using the compressive testing machine that applies an increased steadily increasing compressive load until the sample shattered. The compressive and flexural strengths were measured by dividing the maximum load at which failure occurred by the specimen's cross-sectional area. The test is hugely valuable for determining if the mortar which will be in construction is sufficient to meet the required benchmark for strength to maintain structural reliability and safety.

IV. RESULTS AND DISCUSSION

The cement mortar's compressive load resistance is defined by the compressive and the flexural strength tests. Mortar samples are typically cast into cubes and cured for a specific period, usually 28 days. Once the curing has concluded, the sample is placed in a compression testing machine, and a load is progressively applied until the specimen fails. The compressive and flexural strength (N/mm^2) is calculated using the maximum load at failure. This test is an important indicator of representing strength and durability in construction, ensuring that design requirements and performance standards are being achieved. Table 2 illustrates the results of flexural and compressive strength testing.

Type	g-C_3N_4 %	Glass powder %	Compressive strength N/mm^2			Flexural strength N/mm^2		
			3days	7days	28days	3days	7days	28days
CM	0	0	52.30	53.30	54.30	6.60	7.40	8.00
SPGM 1	0.5	5	52.40	53.34	55.60	6.90	7.80	8.80
SPGM 2	1	10	51.40	51.20	53.40	6.80	7.60	8.40
SPGM 3	1.5	15	51.60	49.30	50.20	6.80	7.50	8.30

Table 2: Compressive and Flexural Strength Results

It reveals that use of g-C_3N_4 and glass powder in cement mortar, may influence its compressive strength, but the influence differs depending on the ration of these additives. With small concentrations applied (0.5% g-C_3N_4 and 5% glass powder), compressive strength is significantly boosted and hence it is indicated that these additives have the potential to positively affect the performance of the material. However, a rise in the percentages of g-C3N4, and glass powder particularly at 1 percent and 1.5 percent of g-C_3N_4 and 10 percent and 15 percent of glass powder leads to a decrease in the compressive strength. This implies that excessive amounts of these additives may degrade the ability of the mortar to resist compressive loads probably as a result of a change in hydration. Consequently, it is essential to fine-tune the mix ratios of g-C3N4 and glass powder in order to achieve an optimal combination of strength and material characteristics in cement mortar.

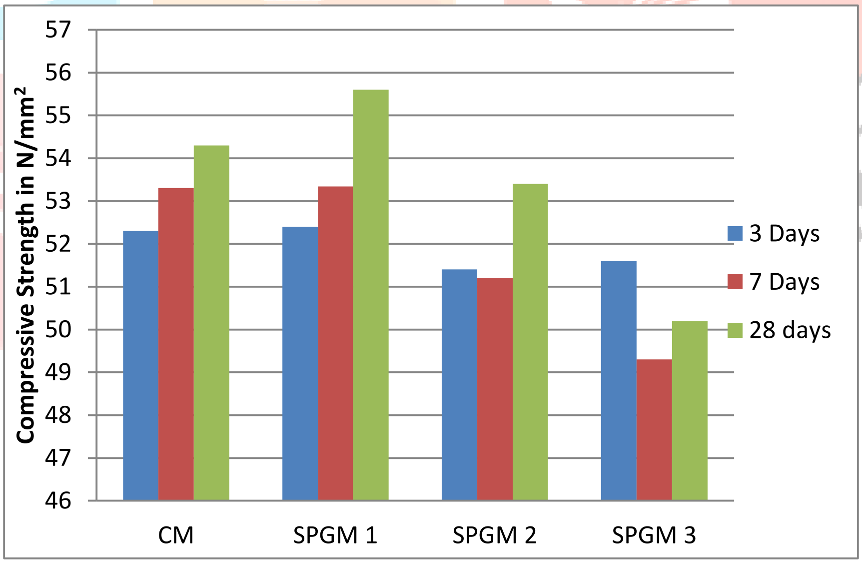

Figure 2: Compressive Strength Test Results

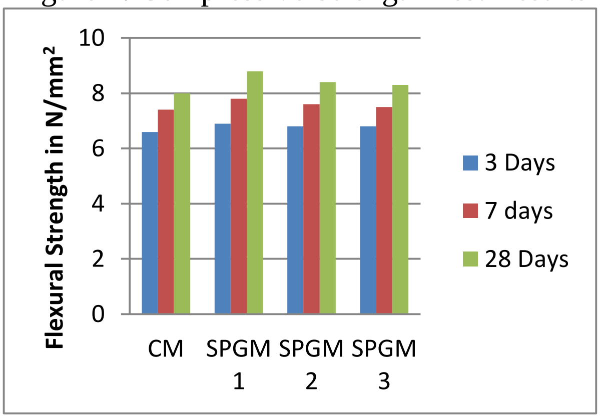

Figure 3: Flexural Strength Test Results

Figure 2 and 3 show the performance variations among the different samples over time. Control mix showed a moderate increase from 14.04 N/mm^2 at 7 days to 15.04 N/mm^2 at 28 days, indicating steady strength development SPGM 1 exhibited the highest strength gain, reaching 16.05 N/mm^2 at 28 days, suggesting more effective material composition SPGM 2 demonstrated moderate strength growth from 12.03 N/mm^2 to 14.04 N/mm^2, while SPGM 3 had the lowest values, increasing slightly from 10.03 N/mm^2 to 11.03 N/mm^2. The graph depicts the development of flexural strength for four types of mortar—Control Mortar (CM), SPGM 1, SPGM 2, and SPGM 3—assessed at 3, 7, and 28 days. In every scenario, the flexural strength shows a consistent increase as curing time progresses, reflecting adequate hydration and strength development over time. At the 3-day mark, the strength of the SPGM mortars slightly exceeds that of the control mix, with SPGM 1 and SPGM 2 demonstrating superior early strength compared to SPGM 3. By the end of the 7 th day all the SPGM samples would have a higher flexural strength compared to the CM with SPGM 1 recording the highest flexural strength. After curing within 28 days, SPGM 1 still stands better than any other mix with a strength of approximately 8.8 N/mm2 at maximum whereas SPGM 2 and SPGM 3 are neck to neck. The control mortar (about 8.0 N/mm 2 after 28 days) is by far the weakest. The findings as a whole leave no doubt that once the sustainable photocatalytic constituents are added to the mortar, its flexural strength is enhanced, particularly that of SPGM 1, which has an excellent performance during the curing phase. Judging by these results, SPGM 1 possesses superior strength characteristics and thus it can be used as an effective alternative to those applications requiring higher compressive capability.

V. CONCLUSIONS

Diverse proportions of g-C_3N_4 to glass powder were tested in the case of making SPGM in this undertaking. The effect of using glass powder and g-C_3N_4 on mechanical strength was examined. The appears of the key results were as follows: The mechanical properties of cement mortar are influenced by the addition of g-C_3N_4, as well as the recycles glass powder. The compressive strength can be strengthened by up to 5 percent GP, and the larger quantities would lead to the decrease in strength. In a comparable manner, the movement brings out the improvement of g-C_3N_4 on mechanical properties with regards to a specific concentration, subsequently the accumulation results in loss of strength. Thus, it is necessary to strength the mortar by determining the optimal proportions of GP and g-$C_3N_4$1

REFERENCES

[1] 1. Lu, L., Yang, Z., Huang, M., Xu, J., Zhou, J., Briseghella, B., &Marano, G. C. (2023). Microstructural and mechanical properties of photocatalytic cement mortar with g-C3N4/CoAl-LDH nanoflowers. Journal of Building Engineering, 74, 106900.

[2] Vulic, T., Hadnadjev-Kostic, M., Rudic, O., Radeka, M., Marinkovic Neducin, R., &Ranogajec, J. (2013). Improvement of cement-based mortars by application of photocatalytic active Ti–Zn–Al nanocomposites. Cement and Concrete Composites, 36, 121-127.

[3] J. Ren, S.Y. Guo, J. Su, T.J. Zhao, J.Z. Chen, S.L. Zhang, A novel TiO2/Epoxy resin composited geopolymer with great durability in wetting-drying and phosphoric acid solution, J. Clean. Prod. 227 (2019) 849–860, https://doi.org/10.1016/j.jclepro.2019.04.203.

[4] L.W. Wang, X. Zhang, X. Yu, F. Gao, Z.Y. Shen, An all-organic semiconductor C3N4/PDINH heterostructure with advanced antibacterial photocatalytic therapy activity, Adv. Mater. 31 (33) (2019), 1901965, https://doi.org/10.1002/adma.201901965.

[5] W.J. Ong, L.L. Tan, Y.H. Ng, S.T. Yong, S.P. Chai, Graphitic carbon nitride (g-C3N4)-based photocatalysts for artificial photosynthesis and environmental remediation: are we a step closer to achieving sustainability? Chem. Rev. 116 (12) (2016) 7159–7329, https://doi.org/10.1021/acs.chemrev. 6b00075.

[6] N. Yang, G.Q. Li, W.L. Wang, X.L. Yang, W.F. Zhang, Photophysical and enhanced daylight photocatalytic properties of N-doped TiO2/g-C3N4 composites, J. Phys. Chem. Solid. 72 (11) (2011) 1319–1324, https://doi.org/10.1016/j.jpcs.2011.07.028.

[7] Abd Aziz, A., Khatun, F., Monir, M. U., Ching, S. L., & Hon, L. K. (2021). TiO 2: A semiconductor photocatalyst. In Titanium Dioxide-Advances and Applications. IntechOpen.

[8] Hamidi, F., &Aslani, F. (2019). TiO2-based photocatalytic cementitious composites: Materials, properties, influential parameters, and assessment techniques. Nanomaterials, 9(10), 1444.

[9] Taoda, H. (2009). Development and applications of photocatalytic Technology industrialization of sustainable eco-technology. Synthesiology English edition, 1(4), 263-272.

[10] A. Fujishima, X. Zhang, D.A. Tryk, Heterogeneous photocatalysis: from water photolysis to applications in environmental cleanup, Int. J. Hydrogen Energy3(14) (2006) 2664–2672, https://doi.org/10.1016/j.ijhydene.2006.09.009

[11] J. Xiong, G.F. Xiao, H.Y. Zeng, C.R. Chen, D.S. An, Construction of heterojunction g-C3N4/CoAl hydrotalcites for high-efficient Cr (VI) reduction under visible light, Appl. Clay Sci. 193 (2020), 105669, https://doi.org/10.1016/j.clay.2020.105669.