ENHANCING CONCRETE MECHANICAL PROPERTIES THROUGH GRAPHITE NANO-MICRO PLATELETS

[a]Hassan Tahir* [b]Muhammad Numan

a: Structure Engineering Department, Designmen Consulting Engineers, Islamabad, Pakistan. hassantahir275@gmail.com
b: Infrastructure Engineering Department, Designmen Consulting Engineers, Islamabad, Pakistan. engr.numans@gmail.com

Abstract- This research explores the enhancement of conventional concrete properties through the incorporation of graphite nano-micro platelets (GNMPs). The experiment involved the addition of GNMPs in varying concentrations of 0.1%, 0.3%, and 0.5% with a testing period of 28 days. The findings revealed a significant improvement in both compressive and tensile strength with the inclusion of 0.3% GNMPs. The research concludes the potential advantages of using GNMPs as an additive in concrete, especially for enhancing strength and increasing the durability and efficiency of conventional concrete. These findings are particularly promising for the construction sector, which is constantly seeking to develop concrete materials that are stronger and more durable.

Keywords- Nano Micro Graphite, Strength Improvement, Durability, Material Testing.

1 Introduction

Concrete, having versatile properties compared to other materials such as strong durability, low maintenance, ease of use, fire resistance, water resistance, and fitting to any shape, is one of the most widely used construction materials in the construction industry globally. As the construction industry grows day by day, it poses more demands, for which conventional concrete alone is not enough to meet the required demands. Because of the low elastic and flexural strength of cementitious materials exposed to breaking, this breaking cycle begins with nanocracks, and with the progression of time, it transforms into microcracks and, afterward, large microcracks inside the grid of concrete. In the beginning, researchers tried to restrict these cracks with the addition of microfibers, although these microfibers do not hold out against the crack at the macro level but slow their transfer to the micro level. It provides a good opportunity for the researchers to increase the mechanical properties of conventional concrete by adding cementitious composites. Little consideration has been shown to investigate the helpful effects of GNMPs in concrete. Incorporating glass powder GP in concrete increases workability and decreases density, absorption, and porosity, with 20% GP being optimal for compressive strength when using conventional mixing methods [1]. Recycled aggregate concrete showed 90% of the compressive and shear strengths of natural aggregate concrete, with a 3% lower modulus of elasticity and 5.5% higher strain at peak stress [2]. This paper describes the effect of the addition of nano-graphite when added to the concrete with different percentages in comparison to the control specimen to investigate the enhancement of mechanical properties such as compressive, tensile, and flexural strengths of conventional concrete.

2 Literature Review

A. Dinesh et al (2023) in his study investigated the effect of nano graphite powder (NGP) and nano silica (NS) on the mechanical properties of concrete. Adding NGP and NS, especially at optimal dosages of 0.3% and 1.5% respectively, significantly improves compressive, flexural, and splitting tensile strength. This enhancement is due to the nano-powder filling gaps and pores within the concrete matrix, resulting in a dense and stronger material [3]. Saha (2017) determined that the compressive strength of concrete-decreases sharply with the addition of fly ash after curing for 28 days [4]. Fly ash decreases the rate of hydration and drying shrinkage of concrete with fly ash is lower than control mix concrete. The absorptivity and chloride permeability are also lower in fly ash concrete [5,6]. The compressive strength, split tensile strength, and flexural strength are maximum when glass powder is replaced by 10% of cement. 20% cement replaced by glass powder gives satisfactory strength. At 28 days the strength of the control mix, the result of compressive strength, split tensile strength, and flexural strength is 45.5 MPa, 7 MPa, and 8.65 MPa respectively. The feasible replacement of cement by glass powder is 20%. [7]

Nakhi et al (2019) found that the density and air content both decrease with an increase in recycled aggregate as recycled has lower bulk density. The slump of concrete is between 60 to 92 mm. When the content of recycled concrete aggregate is increased, the compressive strength of concrete is decreased. 40% replacement of recycled aggregate with natural aggregate shows satisfactory compressive strength. After 28 days of saturation in chloride, the diffusion of chloride increases with an increase in the content of recycled concrete aggregate. [8]. Another study showed that adding 5% nano-graphite platelets by cement weight to concrete with recycled coarse aggregate improves compressive strength by 3.86% [9].

3 Physical properties

Physical properties, elemental details, and chemical composition of raw graphite and Acacia gum have been shown in Table 1 respectively [10].

Table 1: Raw graphite and Acacia gum properties

Property	Raw graphite	Acacia gum
Density g/cm^3	2.23	1.4
specific gravity	1.9	1.35
Surface area m^2/g	24	-
Color	Steel grey to black	-
Luster	Metallic	-

4 Workability

As per ASTM C-143, a slump test was performed to check the workability. To attain a slump in between 75-100 mm, several trails were performed. It was observed that a drop of 8.89 %, 21.26%, and 29.82% occurred as the percentage of GNMPs increased from 0 % to 0.1%, 0.3%, and 0.5% respectively as shown in Table 2. The reason for the drop in slump was that GNMPs have more tendency to absorb water and have a greater surface-to-volume ratio.

Table 2: Workability

WORKABILITY		
	Slump (mm)	% Reduction
0% (Control)	98	-
0.10%	90	8.89
0.30%	74	21.62
0.50%	57	29.82

5 Flexural Strength

Table 3 below shows the flexural strength with respect to percentages of GNMPs. It shows the maximum value of 4.76 MPa when 0.3% GNMPs were added to the mix.

Table 3: Results

Control	Flexural Strength MPa
0%	3.85
0.10%	4.31
0.30%	4.76
0.50%	4.48

6 Compressive Strength

As per ASTM C-39. After curing concrete cylinders for 28 days, in Fig 1. compression testing was performed on the Concrete cylinders having size of 100mm x 200mm. For the compression test, the specimen was removed from curing tank after complete curing time. For 24 hours, the specimen was placed in the lab to dry in the air. Afterward, the specimen was placed in a compression testing machine. The load was applied to the cylindrical specimen. The load was applied in a controlled manner so that the loading rate was the same during the whole test. The loading rate applied on the cylindrical specimen was 0.25 MPa/sec. The result in Table 4 shows an increase in the compressive strength of concrete with the addition of GNMP'S.

Table 4: Compressive Strength Test Results

COMPRESSIVE								
Control	Max Load (KN)	Max Strength (KN)	Max Load (KN)	Max Strength (KN)	Max Load (KN)	Max Strength (KN)	Avg	
							Load (KN)	Strength (MPa)
0%	158.0405	20.1224	155.9228	19.8527	158.2235	20.1457	157.396	20.04
0.10%	222.655	28.3493	133.524	17.0008	172.354	21.9447	176.178	22.432
0.30%	191.45	24.3792	203.2007	25.8724	183.8808	23.4125	192.844	24.555
0.50%	181.4327	23.1008	181.263	23.0791	182.5637	23.2448	181.753	23.142

Figure 1: Compression test assembly

From the results it is concluded that the compressive strength of concrete cylinders after 28 days of curing is 20.04 MPa at 0%. It can be seen in Table 4 that a gradual increase in compressive strength occurs by the addition of GNMPs in concrete cylinders. The compressive strength of graphene concrete cylinders is 22.43 MPa, 24.55 MPa, and 23.14 MPa by the addition of 0.1 %, 0.3 %, and 0.5% GNMP respectively. Optimum compressive strength occurs at 0.3 % of GNMP's; which is 24.55 MPa.

7 Tensile Strength

As per ASTM-C496, a tensile strength test was performed on the concrete beams. The results are shown in Table 5 respectively against the concrete cylinders having no GNMPs.

Table 5: Splitting Tensile Test Results

SPLITTING TENSILE								
Control	Max Load (KN)	Max Strength (KN)	Max Load (KN)	Max Strength (KN)	Max Load (KN)	Max Strength (KN)	Avg	
							Load (KN)	Strength (MPa)
0%	141.07	4.491	134.605	4.285	103.7265	3.302	126.467	4.026
0.10%	141.98	4.52	142.61	4.54	143.24	4.56	142.61	4.54
0.30%	150.15	4.78	151.09	4.81	148.58	4.73	149.94	4.773

0.50%	144.81	4.61	144.18	4.59	142.93	4.55	143.973	4.583

From the results it is concluded that the tensile strength of concrete cylinders after 28 days of curing is 4.026 MPa at 0%. It can be seen in Table 6 that a gradual increase in tensile strength occurs by the addition of GNMPs in concrete cylinders. Tensile strength of graphene concrete cylinders is 4.54 MPa, 4.773 MPa, 4.58 MPa by the addition of 0.1 %, 0.3 % and 0.5% GNMP's respectively. The highest tensile strength occurs at 0.3 % of GNMPs; which is 4.773 MPa.

8 Results and Discussion

Adding GNMPs to concrete increases the packing density of the concrete, which leads to a stronger and more durable material. GNMPs also improve the adhesion between the cement and the aggregate, which further strengthens the concrete. Additionally, GNMP's can help to prevent cracks from forming in the concrete. Significantly, the results show that the compressive strength of the concrete cylinders increased from 20.04 MPa to 24.55 MPa when 0.3% GNMPs were added. The tensile strength of the concrete beams also increased from 2.9 MPa to 4.2 MPa when 0.3% GNMPs were added.

9 Conclusion

A comprehensive investigation into the impact of incorporating Graphite Nano-Micro Platelets (GNMPs) on the properties of concrete. The primary objective of the research is to assess how the addition of different percentages of GNMPs influenced the mechanical and durable properties of conventional concrete in comparison to a control specimen. The experimental study involved the use of 0.1%, 0.3%, and 0.5% GNMPs, with a testing duration of 28 days. Adding Nano Graphite to the concrete mixture increased the flexural strength of concrete cylinder by 4.76 MPa at 0.3%

Compressive strength and tensile strength of the concrete cylinders also showed an improvement with the addition of GNMPs, the strength at 0.3% GNMPs reached 24.55 MPa while the control sample achieved 20.04 MPa. The highest tensile strength was observed at 0.3% of GNMPs with a value of 4.773 MPa, compared to the control sample at 4.026 MPa. It is important to note that these research findings provided valuable insights into the potential benefits of GNMPs as a concrete additive, particularly in terms of strength enhancement and improved resistance to water penetration. These findings hold promising implications for the construction industry, where the development of more durable and resilient concrete materials is of utmost importance.

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