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INFLUENCE OF GRAPHITE POWDER ON STRENGTH AND DURABILITY PROPERTIES OF CEMENT MOTAR

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Abstract

In this study, the combined effect of different amount of graphite powder as a substitute for sand and three cure methods on the strength and durability properties of cement mortar have been investigated. The results can be concluded that graphite powder can effectively improve the strength of cement based materials. To meet the objectives, cement mortar mix is prepared with various percentage of graphite powder that is 0.1%, 0.5%, 1%, 1.5% and 2% strength and durability properties are obtained from compressive strength test, split tensile. From the results the optimum percentage of addition of graphite powder to cement motor is determined to without effecting properties of the cement motor.

Key words: Durability, Concrete, Strength,

1. Introduction

High-performance concrete is desperately required in essential projects like high-rise structures, cross-sea bridges, subsea tunnels, and hydraulic or marine works, which are frequently exposed to salts and alkalis and are quickly destroyed [1]. Constructing a high-performance structure with high-performance concrete necessitates the use of materials that have a number of advantages over conventional concrete, such as increased strength and durability as well as improved chloride-ion migration resistance as well as freeze and sulphate resistance [2]. The fractured nature of cement composites is seen in their strong compressive strength but poor tensile and flexural strength. Composites made of cement and carbon fibres ha2ve been improved by using new carbon materials such as carbon fibres, carbon nanotubes, and carbon black [3]. Researchers attempted to alter the cement mortar by using nanomaterials as the technology advanced. It is well known that nanomaterials have a small particle size, a large specific surface area, and a high specific surface area [4]. The compressive and flexural strength of cement mortar can be greatly enhanced by the use of

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nanomaterials.

Graphite powder is an inorganic material with high electrical and thermal conductivity. Therefore, it is often used as a conductive material in industrial products (5). In 2001, a new type of conductive concrete was prepared by using graphite products (6). In 2001, conductive concrete was successfully applied to the bridge deck of Roca Spur bridge in Nebraska Prefecture, and better de-icing results were achieved as result of its thermoelectric effect (7). However, the water demand of graphite powder is very high, and the water consumption for the concrete mixture is greatly increased. The strength of concrete decreases rapidly with increasing graphite powder dosage (8). It means that graphite can improve the conductivity of concrete but reduce the strength. Currently, most researchers pay attention to nano-additives of various carbon allotropic forms (graphite, graphene, nano tubes etc.,). The unique properties of carbon nanostructures [9] allow to predict high mechanical properties of composites modified by additives on the basis of carbon. Some studies observed that additives based on carbon considerably increased the crack resistance of cement stone during exothermic reactions, especially those which intensively occur at the initial stage of cement hydration [10].

2. Literature Review

Ting Luo and Qiang Wang (2021) reported that "Workability" refers here to the ease of flow and consolidation in fresh cement composites, which significantly affects the mechanical properties and durability of hardened cement composites. Many researchers have reported that the addition of graphite adversely affects workability. Ting Luo and Qiang Wang (2021) Increasing the content or fineness of graphite drastically reduces its fluidity due to the inter-particle friction with cement particles and the low hydrophilicity of graphite. reported that the spread diameter of cement paste with 4% graphite content is reduced by about 50%.Ting Luo and Qiang Wang (2021) reported that the incorporation of 7% graphite (by volume) can reduce slump by 33%; the slump reduction was in a nearly linear relationship with the increase in graphite replacement level due to the very high surface area of graphite.A.M. Brandt et Al (2014) proves that, The addition of graphite powder considerably reduces the flowability of the mixtures due to its filling effect in the matrix of the composite.Kamal H. Butrouna (2000) noted that, Increasing graphite content beyond 1% proved to be harmful to the electrical and physical properties of concrete. This can be attributed to the fact that more graphite produces a drier fresh mix and a denser concrete.JL Gao & ZC Shao (2012). Noted that The effects of graphite concentration on thickness,

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roughness, friction coefficient and phase composite of ceramic coating were investigated. The results indicated that the roughness and friction coefficient of ceramic coatings increased linearly. However, the thickness decreased adding graphite powder.M. Mar Barbero-Barrera et al. (2017) reported that graphite waste is synthetic pure graphite, a specific form of carbon. Its properties as BET surface area of 26.3078 ± 0.2622 m2 /g and a micropore area of 1.7052 m2 /g. Furthermore, the main particle size determined by laser diffraction and ranged from 1–10 lm, in which the peak from 35–150 lm was caused by the agglomeration of particles due to electro static forces.Ting Luo and Qiang Wang (2021) noted that Viscosity increased progressively as graphite content increased beyond 40%(by wt), alternatively reduces the fluidity of cement paste. the Cement paste flow diameter decreased from 25.5 cm to 9.5 cm after 30% graphite addition.

3. Experimental Programme

3.1 Materials

In this study cement was used to prepare graphite powder cement composites and control. OPC 53 grade cement was used in the production graphite powder-based cement composites. The Fine aggregates are used as sand and is collected from the locally available natural river. Graphite powder used in this study is obtained from India Mart Limited, India**.** Physical and mechanical properties of Materials and tests on aggregates are listed in below tables 1.1&1.2. Materials used are a) cement b) fine aggregate and c) graphite powder as shown in below Fig. 1.1, 1.2 and 1.3, respectively.

Table 1: physical and mechanical properties of materials

Materials	Cement	Graphite powder
Specific gravity	3.11	1.92-2.34
Fineness	5%	20%
Normal consistency	31%	32%
Soundness	10mm	10-12mm
Initial setting time	50 min	65min
Final setting time	210 min	215min

Table 2: Tests on aggregates

Aggregate	Tested value	Standard value	Reference code
Specific gravity of fine aggregate	2.63	2.5-2.9	IS 2386-1963
Zone of sand	Zone -2	Preferably zone-2	IS 383-1973

In this research work, cement composites were prepared using graphite powder dosages of 0, 0.1%, 0.2%, 0.5%, 1% and 1.5%, respectively, as a percentage of the cement weight. The Mix proportion if cement mortar (CM) ratio is 1:2.

Table 3 Mix calculation of GP-based cement composites in kg/m^3

Mix id	Cement	GP (%)	Fine aggregate	Water
C	410	-	820	164
CG1	410	0.1	820	168
CG2	410	0.5	820	171
CG3	410	1.0	820	173
CG4	410	1.5	820	176
CG5	410	2.0	820	177

4. **Result and Discussions**

4.1 Fluidity

One of the most important procedures for determining the workability of cement composites was the fluidity test. A flow table test was used to determine the effect of graphite powder on the fluidity of cement composites. A significant decrease in the fluidity of the cement mortar was observed when Graphite powder was added.

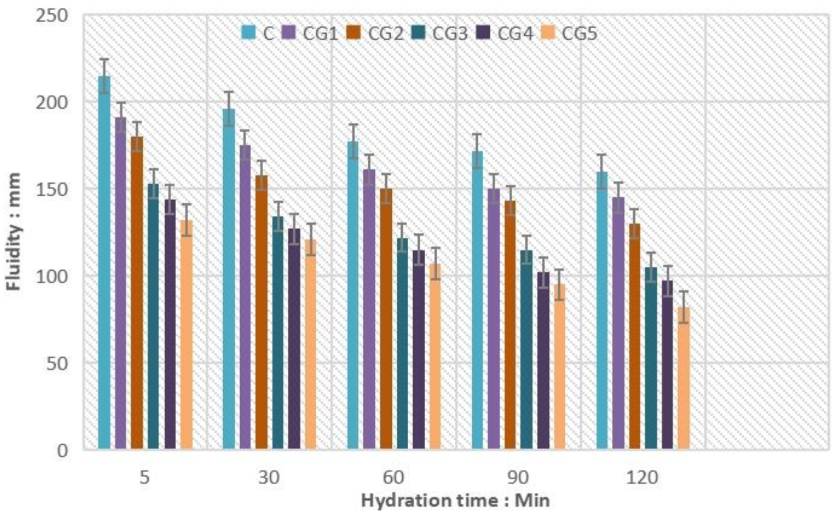

Figure 4.1 Cement paste fluidity chart with GP cement composites

Fig. 4.1 indicates the rate of flowability decreased by the addition of graphite powder in cement mortar and also by the increase in the hydration time the quick setting of specimen was noticed. For 5 min of hydration time the fluidity for the mixes C, CG1, CG2, CG3, CG4 and CG5 are 215, 191, 180, 153, 144 and 132 mm, respectively. For 30 min of hydration time the fluidity for the mixes C, CG1, CG2, CG3, CG4 and CG5 are 196, 175, 158, 134, 127 and 121 mm, respectively. For 60 min of hydration time the fluidity for the mixes C, CG1, CG2, CG3, CG4 and CG5 are 177, 161, 150, 122, 115 and 107 mm, respectively. For 90 min of hydration time the fluidity for the mixes C, CG1, CG2, CG3, CG4 and CG5 are 172, 150, 143, 115, 102 and 95 mm, respectively. For 120 min of hydration time the fluidity for the mixes C, CG1, CG2, CG3, CG4 and CG5 are 160, 145, 130, 105, 97 and 82 mm, respectively. the lowest fluidity value was observed after 120 min of hydration time in the mix CG5, by the addition of 0.05% of GP content in cement mortar hence, the fluidity values decrease when compared to cement mortar, also with increase of time.

4.2 Water absorption

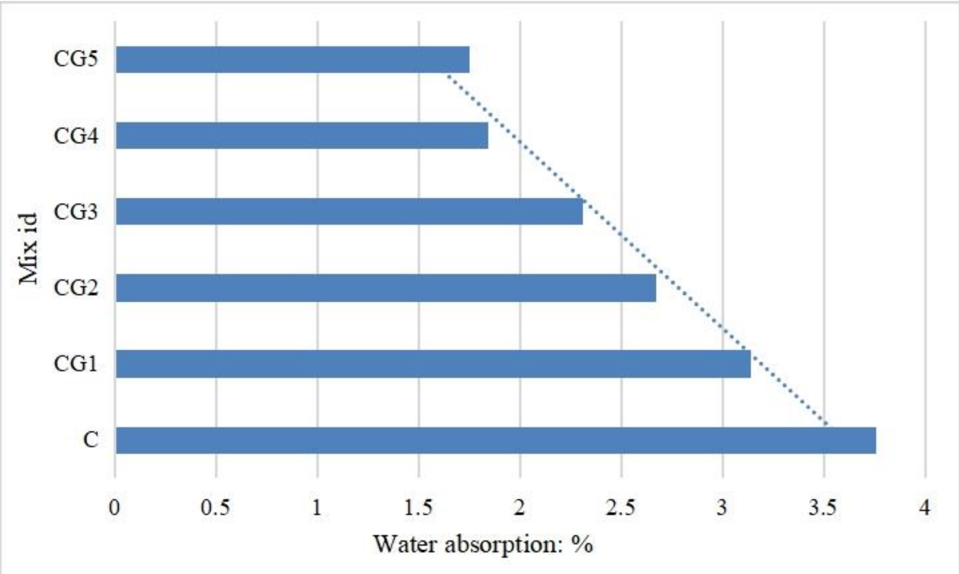

Figure 4.2 water absorption percentage of GP-cement composites

Fig. 4.2 describes about water absorption in percentage is determined. By mixing of graphite powder content in cement mortar the rate of water absorption is decreased, water absorption for the mixes C, CGP1, CGP2, CGP3, CGP4 and CGP5 are 3.76, 3.14, 2.67, 2.31, 1.84 and 1.75%, respectively. The trend line defines gradual decrease of water content in cement composites of different mixes, the lowest water content was observed in CGP5 for 1.5% GP and highest water content was in normal cement mortar. the trend line indicated by dotted line in the form inclined towards left side.

4.3 Sorptivity

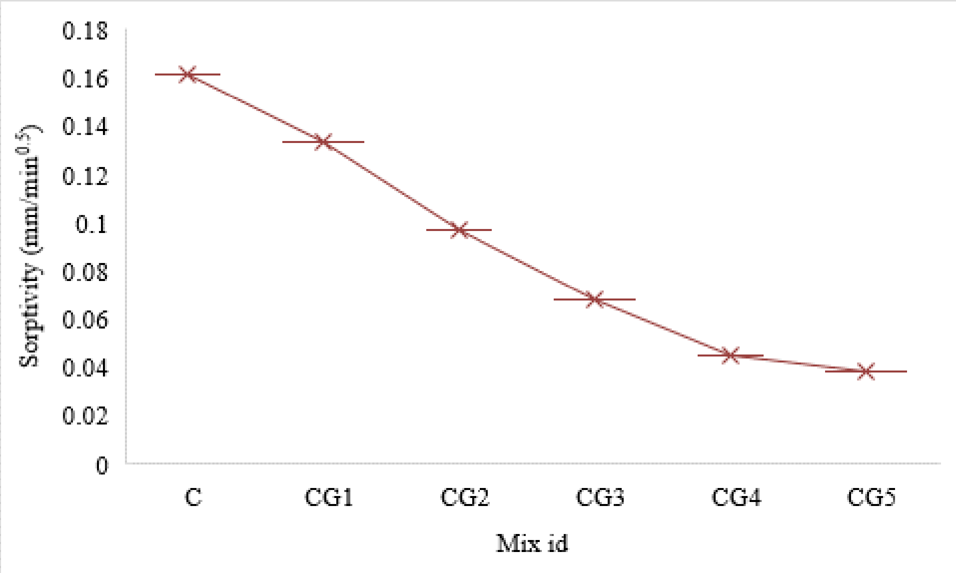

Figure 5.3 sorptivity of GP-cement composites

Fig. 5.3 indicates penetration of water through capillary suction in the specimen is determined by using sorptivity test. the sorptivity value for the mixes C, CGP1, CGP2, CGP3, CGP4 and CGP5 are 0.161, 0.133, 0.097, 0.068, 0.045 and 0.038 $mm/min^{0.5}$, respectively. the sorptivity values was decreased by the increase of graphite powder content in cement mortar, lowest sorptivity value was observed for CG5 when compared to C mix.

4.4 Chemical resistance test:

The chemical resistant of C, CGP1, CGP2, CGP3 and CGP4 cement paste sample cured in the mix of acids (H2SO4 & HCL) and water bath for 3 days. The results of chemical resistance test of cement composite mixes are given in Table 3 & 4. Chemical resistance of mixes are measured in terms of weight loss, dimension loss and compressive strength. The specimens after acid resistance test is shown in Fig. 5.4. As per test results, there is no change in dimension loss after immersion of both acid solutions. Weight loss and compression strength of mix C & CGP4 are 1.94% & 0.67% and 36.88 & 46.98 mpa values are observed in immersion of sulphuric acid solution. Mix C & CGP4 are 1.92% & 0.64% and 35.62 & 44.12 mpa values are observed in immersion of hydro chloric acid solution. The durability of each group of cement paste increases. However the addition of graphite significantly improve the durability of cement paste after 3 days acid curing.

Fig 4.4 Acid curing specimens

Table 4: Sulphuric acid resistance test results.

Mix id	Weighth before immersion (kg)	Weight after immersion (kg)	Weight loss (%)	Dimensions before immersion (mm)	Dimensions after immersion (mm)	Comppressive strength (mpa)
C	0.770	0.755	1.94	70.6*70.6	70.6*70.6	36.88
CGP1	0.760	0.750	1.31	70.6*70.6	70.6*70.6	35.28

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CGP2	0.765	0.755	1.30	70.6*70.6	70.6*70.6	36.77
CGP3	0.775	0.770	0.64	70.6*70.6	70.6*70.6	38.56
CGP4	0.745	0.740	0.67	70.6*70.6	70.6*70.6	46.96

Table 5: HCL acid resistance test results.

Mix id	Weight before immersion (kg)	Weight after immersion (kg)	Weight loss (%)	Dimensions before immersion (mm)	Dimensions after immersion (mm)	Compressive strength (mpa)
C	0.775	0.760	1.92	70.6*70.6	70.6*70.6	35.62
CGP1	0.745	0.735	1.34	70.6*70.6	70.6*70.6	22.13
CGP2	0.770	0.760	1.29	70.6*70.6	70.6*70.6	24.75
CGP3	0.780	0.770	1.28	70.6*70.6	70.6*70.6	37.71
CGP4	0.780	0.775	0.64	70.6*70.6	70.6*70.6	44.14

4.5 Compressive strength

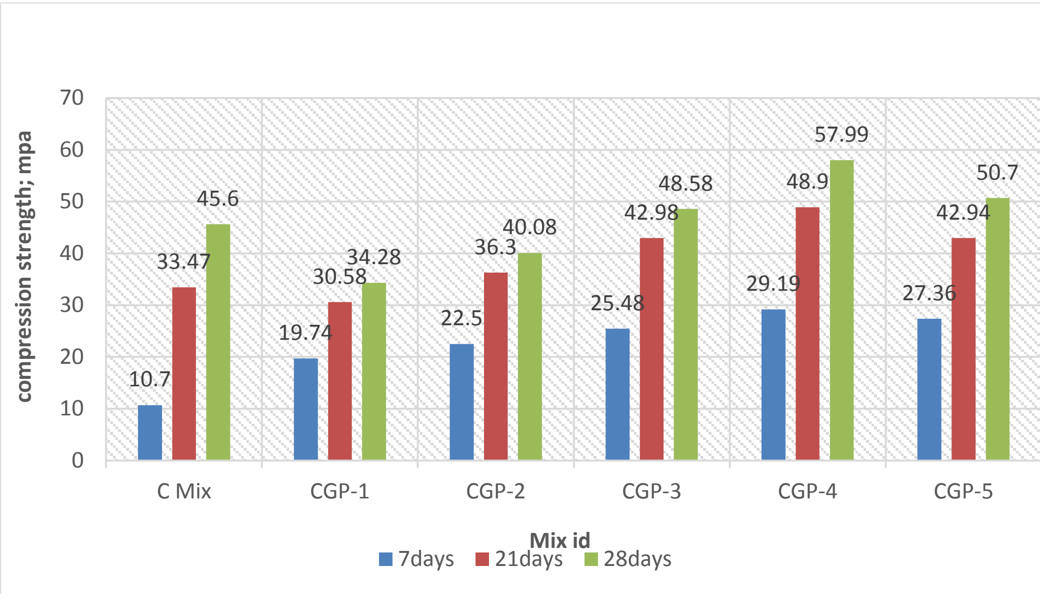

Figure 4.5 compression strength of cement composites

The compressive strength of C, CGP1, CGP2, CGP3, CGP4, and CGP5 cement paste samples cured in water bath for 7 d, 21 d, and 28 d was tested. The experimental results are shown in Fig 4.5 describes various colours. It can be seen from the figure that the compressive strength of each group of cement pastes increased with the increase of curing

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time. However, the addition of graphite did not significantly improve the compressive strength of cement pastes for 7 d and 21 d. After curing for 28 d, it showed an improvement effect on the compressive strength of the cement pastes. After curing for 28 d, the compressive strength of the cement pastes increased first and then decreased with the increase of graphite content. At this time, the compressive strength for the mix C of different days 7, 21 and 28 days are 10.7, 33.44 and 45.60mpa, respectively. the compressive strength for the mix CGP1 of different days 7, 21 and 28 days are 19.74, 30.58 and 34.28mpa, respectively. the compressive strength for the mix CGP2 of different days7, 21 and 28 days are 22.5, 36.30 and 40.10mpa, respectively. the compressive strength for the mix CGP3 of different days 7, 21 and 28 days are 25.48, 42.98 and 48.58mpa, respectively. The compressive strength for the mix CGP4 of different days 7, 21 and 28 days are 29.19, 48.90 and 57.99mpa, respectively. The compressive strength for the mix CGP5 of different days 7, 21 and 28 days are 27.36, 42.94 and 650.70mpa, respectively. From C to CGP4 the compressive strength increase's, thereafter for CGP5 the compressive strength decreased when compared to CGP4, therefore for CGP4 the maximum compressive strength is obtained by addition of 1.5% graphite powder in cement mortar is observed.

5.6. Splitting tensile strength:

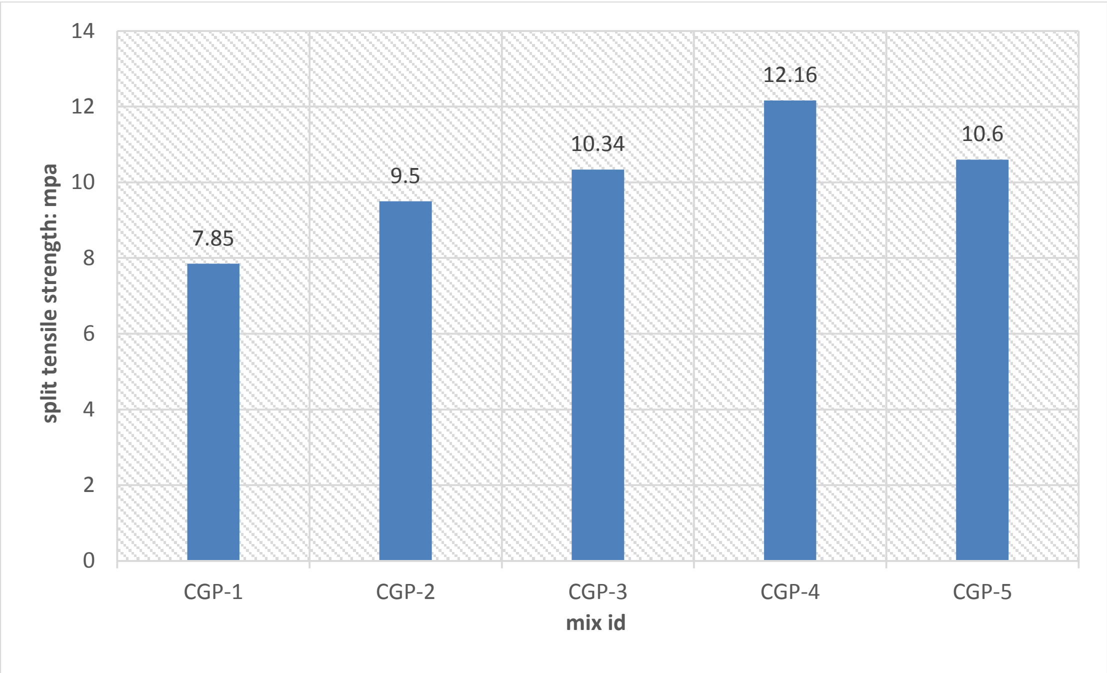

Figure 4.6 split tensile strength of cement composists.

Fig. 4.6 indicates the splitting tensile strength of cylinder is obtained after 28 day's curing. tensile strength for the mixes C, CGP1, CGP2, CGP3, CPG4 and CGP5 are 7.85, 9.50, 10.34, 12.16, and 10.5 respectively. the tensile strength value's increased up to CG4, thereafter decreased for CG5.the maximum splitting tensile strength is obtained in the CG4 mix by the addition of 1.5% graphite powder in the cement mortar.

4.7. Modulus of elasticity:

load and displacement for the mix CGP1 is 83.21kn & 2.12mm. mix CGP2 is 99kn & 2.29mm mix CGP3 is 101.91kn & 2.39mm. mix CGP4 is 96.15kn & 2.55mm respectively. The load vs deflection values increased up to CGP3, thereafter decreased for CGP4. The maximum load vs deflection is obtained in the mix CGP3 by the addition of 1.0% graphite powder in the cement motor.

5. Conclusions:

In this paper the influence of graphite powder on the mechanical and durability properties of cement composites was presented. The experimental results have shown a positive impact by addition of graphite powder in cement composites. The following conclusions are drawn by the addition of various wt% of graphite powder in cement composites.

- The fluidity of cement composites was decreased due to the addition of graphite powder. Increase in the amount of GP the decrease in the fluidity was also observed. This proves that the inclusion of graphite powder enhance the hydration process of cement composites.
- Due to the incorporation of GP the denser matrix formation was notices that leads to the decrease in the water absorption and sorptivity of GP-based cement samples. This indicates that the pore structure was minimized with the addition of graphite powder in the cement samples and durability of the structure can be increased.
- At graphite powder concentration of 1.5%, compression strength increased by the 69.16%, while at a 2%, compression strength was 50.34% after 28 days when compared to the control mix. Based on results notice that increase the graphite powder content decrease the compression strength.
- At graphite powder concentration of 1.5%, split tensile strength increased by the 54.90%, while at a 2%, split tensile strength 35.03% after 28 days when compared to the control mix. Based on results notice that increase the graphite powder content decrease the tensile strength.

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