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Effect of Graphene oxide Addition on Cement-Sand Mortar

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Abstract

The effect of addition of graphene oxide (GO) to the cement-sand mortar on its fluidity and strength was investigated. The dosages of GO addition were varied from 0.03% to 0.06% by weight of cement. The GO was sonicated with required water for uniform mixing and added to the dry mixture of Ordinary Portland Cement and sand of proportion 1:2 (by weight). The incorporation of GO in cement- sand mortar reduced its fluidity compared to control mortar (without GO). A maximum reduction in fluidity of 32% was noted for the GO addition of 0.03%. The compressive strength of mortar was enhanced with the addition of GO (up to 0.05%). However, such enhancement was reduced with further addition of GO. The 0.05% of GO addition increased the compressive strength of mortar by 49.8%, 25.6% and 20.3% compare to that of control sample at 3 days, 7 days and 28 days respectively. The flexural strength of GO based cement sand mortar was also increased substantially compared to control mortar at 0.05% GO addition. More flake like hydration products were observed in GO based cement sand mortars by field emission scanning electron microscopy (FESEM).

Keywords: Graphene oxide, Cement mortar, Fluidity, Compressive strength, Flexural strength.

1. Introduction

Cement based construction materials are most widely used for building, road, bridge and various other types of civil engineering construction. However, it has its own limitation because of its lesser tensile strength and brittleness. By providing steel bars [1], it possible to increase its resistance against tension. The incorporation of different admixture [2] and fibres [1,2] are at present most valuable techniques to Improve its overall performance. Recently carbon-based nanomaterials such as carbon nanotubes (CNTs) and graphene have pulled the attention in improving the performance of such cementitious materials [2] because of their amazing physical and mechanical properties. It was shown that the addition of very less amount of carbon nanotubes (CNTs) increase the mechanical properties of cementitious materials [3,4] and enhanced also the mechanical and chemical properties of fly-ash based geopolymers [5].

Graphene (G) and graphene oxide (GO) are new members in the world of carbon based nanomaterial. Graphene is a single layered and considered as two dimensional (2D). GO is basically a graphene derivative and it has various oxygen-containing functional group such as hydroxyl, carbonyl, epoxy and carboxylic groups. It has huge surface area and high mechanical properties [6, 7]. This makes GO potentially more favourable than 0D nanomaterials and 1D nanotubes for altering various matrix properties.

The aim of the present research work is to incorporate GO in cement sand mortar at various dosages (0.03% to 0.06% by weight of cement) and to investigate its effect on mechanical properties of cement-sand mortar. The microstructure analysis of cement-sand mortar (with/without GO) was also performed by field emission scanning electron microscope (FESEM).

2. Materials and Experimental Methods

2.1 Materials

Ordinary Portland Cement (OPC) grade 53 confirming to IS: 12269-1987 [9] was used throughout the experimental study. The chemical compositions of OPC are presented in Table 1. Locally available river sand of Grade-II (as per IS: 383-2016) and specific gravity of 2.66 was used. The properties of GO collected from M/s Ad-Nano Technologies Pvt. Ltd, Karnataka, India was presented in Table 2.

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Table-1. Chemical composition OPC 53 grade

Parameters	Percentages
SiO_2	21.94
Al_2O_3	4.95
Fe_2O_3	3.74
CaO	62.33
MgO	2.08
SO_3	2.22
K_2O	0.56
Na_2O	0.32
Others	1.89

Table-2. Technical properties of GO

Descriptions	Graphene oxide
Purity	>99%
Numbers of layers	1-3 layers
Average thickness (z)	0.8-1.6nm
Average lateral dimension (x & y)	5-10 µm
Surface area	450m2 /g
Carbon	66%
Oxygen	32%
Others	2%

2.2 Mix Proportion and curing

To investigate the effects of addition of GO in cement mortar, cement sand ratio was taken as 1:2 and the water to cement ratio was kept as 0.45 for all the mixtures. The amount of GO added into cement sand mortar are 0.03%, 0.04%, 0.05% and 0.06% by weight of cement. The cement and sand was mixed thoroughly 3-4 minutes in dry condition. Sonicated mixture of require amount water and GO was added. Then the mortar was placed into standard steel mould and well compacted. The hardened cement mortar was demoulded after 24 hours and immediately placed in water for curing till testing. Details of different mixtures are shown in table 3.

Table-3. Details of different mixtures and its flow test results

Mix designation	Control	GOPC-3	GOPC-4	GOPC-5	GOPC-6
Cement (gm)	726	726	726	726	726
Sand (gm)	1452	1452	1452	1452	1452
GO % (by weight of cement)	0.00	0.03%	0.04%	0.05%	0.06%
% of flow (as per flow table test)	42	10	13	20	16
Reduction of flow %	-	23	20	15	18

3. Preparation of Cement Mortar Sample and Testing

3.1 Fluidity Test

The fluidity of cement sand mortar mixes with/without GO was measured by using flow table test as per IS: 4031 (part 7) – 1988 [10]. The dimensions of the con are top diameter 50 mm, bottom diameter 100 mm and height 50 mm. the con was fixed firmly on flow table. The fluidity was measured from the initial and final diameter after test.

3.2 Sample Preparation for Compressive Strength and Flexural Strength Test

To study the effect of addition of different doses of GO on the mechanical properties of cement mortar, the compressive strength tests were conducted using standard cement mortar cube specimens of size 70.6 mm × 70.6 mm ×70.6 mm [11]. For the compressive strength test, hardened cement mortars were tested at different ages of 3 days, 7 days and 28 days. Flexural strength test was also carried out on 50 mm ×50 mm × 200 mm cement mortar bar at different dosages of GO. These specimens were tested after 28 days water curing. The center point method was adopted for the determination of flexural strength (AASHTO T 67) (12) of span 150 mm.

3.3 Sample Preparation for FESEM Analysis

After compressive strength test at 28 days, the fragments of cement sand mortar with/without GO were crushed to powder separately and were examined under FESEM (INSPECT F50 SEM, FEI Europe BV, Eindhoven, the Netherlands) to obtain micrograph.

4. Result and Discussion

4.1 Fluidity Test

The results of flow table test for different mixes are tabulated in table 3. It is noted that the fluidity of cement mortar decreases with respect to control sample (without GO) with the addition of different percentage of GO. Maximum reduction in fluidity of 23% was observed for the incorporation of 0.03% of GO. The reduction in fluidity of GO based cement-sand mortar may be due to the high specific surface area of graphene oxide. Further, graphene oxide interacted with cement particles and thereby agglomerates and flocculation was formed. The large surface area of graphene oxide with high absorption of free water on its surface leads to the decrease in fluidity [3].

4.2 Compressive strength

Fig. 1 shows the compressive strength of cement-sand mortar sample with and without GO. It is noted that the compressive strength of cement mortar increases

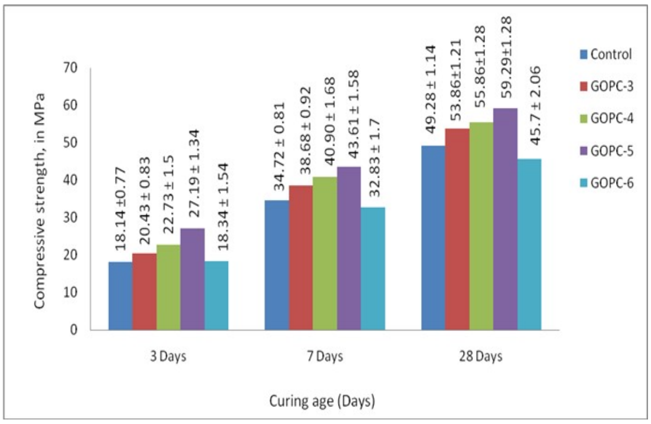

Fig 1. Compressive strength of different mixes at different ages

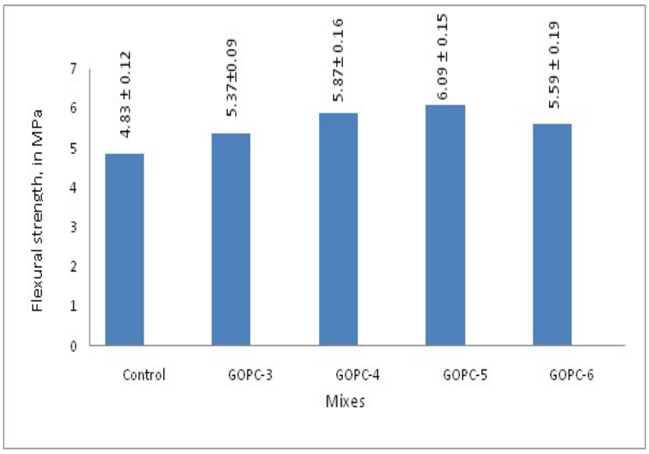

Fig 2. Flexural strength of different mixes at 28 days

prominently with the increase in GO addition up to 0.05% by weight of cement at all ages. However, with further addition (at 0.06% GO) the strength is decreased at all ages.

4.3 Flexural Strength

Fig.2 indicates the variations of flexural strength of cement sand mortar with and without GO. The maximum tensile strength at 0.05 addition of GO was 6.09 MPa compared to that of control sample of 4.83 MPa. Similar trend obtained as in the case compressive strength results.

4.4 Micro-Structural Analysis by FESEM

The FESEM images of cement sand mortar for control sample and GOPC5 are shown in Fig. 3 (a) and Fig. 3 (b) respectively. Large amount of flake like hydration products observed in GOPC-5 compare to control sample (without GO). The enhancement of compressive strength of GO based cement-sand mortar may be due to the presence of more such hydration product that fill the pore area of cement sand mortar and improve the pore structures. It has also noted that GO could have regulate have regulate the form of flower-like, polyhedral and lamellar hydration products of cement paste which form denser structures [13, 14].

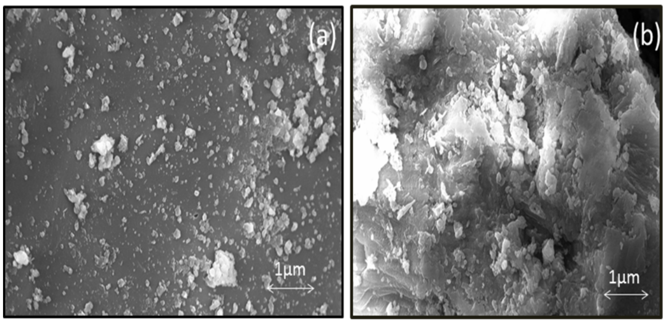

Fig3. FESEM image of cement-sand mortar (a) control sample and (b) GOPC-5

5. Conclusions

The fluidity of the cement sand mortar is reduced with the incorporation of GO. This reduction of fluidity is due to the formation of GO agglomerates which have high water entrapment capacity and high specific surface area. The maximum reduction of fluidity of GO based cement sand mortar noted at 0.03% addition of GO. Addition of GO also increases the compressive strength of cement sand mortar at different ages. The maximum enhancement of compressive strength was noted at 0.05% GO addition. Further, the enhancement in compressive strength is more pronounced at 3 days compared to 28 days. The tensile strength of cement sand mortar is also increased with the addition of GO and the optimum % of GO addition is noted as 0.05%.The improvement in strength seems to be due more refined pore structures with the formation of hydrated flake like product.

Disclosures

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