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Comparative Study on Reinforcing Effect of Graphene Oxide in Cement Mortars with River Sand and M-Sand

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Abstract

In the recent era, graphene oxide, a new member of the nanomaterial family, has grown in significance. In this study, River Sand (R-Sand) and Manufactured Sand (M-Sand) are being used as aggregate in cement mortars to assess the reinforcing impact of graphene oxide. The study examines effects of various graphene oxide concentrations on the compressive strength and flexural strength of the cement mortar's mechanical and microstructural features. The study's findings show how graphene oxide can be used as a reinforcing agent in cement-based products and how R-sand and M-sand perform differently when utilized as fine aggregate. The comparison of cement mortar with and without superplasticizer for both R-sand and M-sand is done once the optimal dosage of graphene oxide has been established. The work sheds light on the possibility of using M-sand as a substitution for river sand and the optimization of graphene oxide concentrations for maximal reinforcement in cement mortar. The optimal GO dosage for R-sand and M-sand was found to be 0.2% and 0.6%, respectively and it is validated through SEM tests.

Keywords: *Graphene Oxide, M-Sand, R-Sand, SEM*

1.0 Introduction

The widespread application concrete and mortar, has led to large consumption of naturally available sand around the world due to the booming infrastructure in emerging and developing nations, there is a sizable demand for natural sand. Globally every year, about 32-50 billion tons of sand is utilized in the preparation of concrete[1]. In the banks of Ganges, about 200 adults were assaulted by wild animals due to illegal extraction of river sand[2]. As a result of cumulative extraction of natural sand from the river beds, numerous problems results, including the lowering of the subterranean water table, which results in the defeat of water-retentive sand strata, expanding of river courses, river bank slides, a vegetation loss of along river banks, intake wells exposure for water supply systems, disruptions of water existence, and farming issues. Developing countries like India are facing a shortage of quality natural sand. This is a severe threat to the environment and society in India due to the depletion of natural sand deposits.

In recent years, manufactured sand is well-known as a suitable substitute source for river sand. As the properties of M-Sand and R-Sand are found to be similar, the particle

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shape, and surface roughness gradation of M-Sand is better than R-Sand. The properties of R-Sand and M-Sand have been widely studied[3]. The mortar properties for the 1:3 and 1:4 ratio was conducted for both R-Sand and M-Sand, and the workable properties, mechanical properties, and durability of fresh and hardened mortar were determined. It was observed that the workability properties of M-Sand are low as compared with R-Sand as the surface unevenness of M-Sand is greater than R-Sand, whereas the mechanical and durability properties of M-Sand were more commendable than R-Sand. Quarry dust sand can be a replacement for natural sand for cement concrete[3].

One of the main constituents of mortar is the binder material, which is cement. The most commonly used and widely popular cement is Ordinary Portland Cement (OPC), due to its availability and versatility. In 2021, cement manufacturing industries produced about 149 million metric tonnes of CO_2 in India[4]. Henceforth, it is highly recommended to determine alternative materials for cement which have cementitious properties. However, cementitious materials are generally brittle and susceptible to cracking. Different types of agricultural wastes, pozzolana, and by-products from industries, etc. possess cementitious properties and are found to be an efficient partial replacement of cement[5-8].

In the past ten years, nano-materials have enhanced cementitious materials to slow the formation and development of nanoscale cracks and stop them from spreading to the micro- and macro-scales. Due to its superior mechanical qualities, Graphene Oxide (GO), a new member of the nanomaterial family, is perfectly able to considerably reinforce cement-based materials. Oxygen-containing functional groups are joined to carbon atoms in Graphene Oxide (GO)[9]. GO is hydrophilic and extremely dispersible in an aqueous solution thanks to the functional groups. When added to cement-based materials, the large surface area may also help to strengthen the bonding between graphene sheets and cement hydration products. As a result, it was discovered that cementitious materials modified with GO had improved mechanical characteristics[10].

The addition of GO into OPC and PPC cement showed increase in flexural strength by 24.5% and 1.7% after 28 days, in which the optimum dosage of GO was found out be 0.04%[11]. When GO was replaced by 0.02%, 0.04%, 0.06%, 0.08% and 0.1%, the one with better results was 0.04%. This replacement of cement was done for PPC and the microstructural, mechanical and durable properties were analyzed. It was observed that the flexural strength for 28 days of 0.04% replaced GO mortar was enhanced by 40.41%[12].

The present work focuses on usage of graphene oxide in cement mortar with a replacement of 0.01-0.1% and to determine the motorized performance of the cement mortar. The primary objective is to investigate the microstructural behavior of Graphene oxide infused cement mortar through Scanning Electron Microscope (SEM) method.

2.0 Experimental Methodology

2.1 Materials

2.1.1 Cement

In this project, we have utilized Ordinary Portland Cement grade 53 which was procured from a nearby construction site.

2.1.2 Manufactured Sand

Manufactured sand widely known as M-Sand is most commonly used as a fine aggregate in cement mortar and concrete. Nowadays, M-sand has gained more popularity due to the unavailability of river sand and its cost-effectiveness. The index properties of M-sand are as indicated in Table 1.

2.1.3 River Sand

River sand has been used as fine aggregates from so many years. Nowadays the resources have been depleted to such an extent that alternatives have been found over the past decade. The properties of river sand have been shown in Table 1. In this article, one of the objectives is to draw a comparison between cement mortar with fine aggregate as R-sand and M-sand.

Table 1. Preliminary Test Results

Property	M-sand	R-sand
Specific Gravity	2.54	2.65
Water Absorption	2.85	2.74
Sieve Analysis	Zone 1	Zone 1

2.1.4 Graphene Oxide

Graphene Oxide (GO) is one of the most promising nanomaterials that has gained importance in the construction industry lately. The chemical composition of graphene oxide is $C_{140}H_{40}O_{20}$. GO is the strongest, lightest, thinnest, transparent, flexible, impermeable, and stretchable material[9]. The properties of GO are shown in Table 2. GO was procured from Ultra-nanotech, Bangalore.

2.2 Methodology

2.2.1 Preparation of GO Mortar with R-sand and M-sand

In this paper, the comparison of cement mortar with and without GO is done between R-sand and M-sand. After the properties of materials are tested, the cement mortar is prepared by mixing cement and fine aggregate in the ratio of 1:3. The water cement ratio adopted after reviewing various literature surveys is 0.5. Firstly, the dry mix is prepared, later the water is added and the mortar is obtained. This mortar is filled into small cubes of size 0.7 x 0.7 x 0.7 mm in three layers. Three cubes of each M-Sand cement mortar and R-Sand cement mortar is casted. The mortar is compacted properly in order to avoid voids. These cubes are allowed to set for 24 hours, later it is placed in curing tank for hydration process to take place. The compaction test is conducted for 7 days in order to monitor the early compressive strength. This procedure is carried for both M-Sand and R-Sand.

In order to analyze the behavior of GO with cement mortar, it is important to determine the optimum dosage of GO to be added into the mortar. Therefore, GO was added to the cement mortar by 0%, 0.02%, 0.04%, 0.06%, 0.08% and 1% to the weight of cement and compressive strength was calculated for curing periods of 7, 28 and 56 days for both types of fine aggregates.

2.2.2 Preparation of GO Mortar with R-sand and M-sand along with Superplasticizer

In order to increase the rheological properties of mortar, the polycarboxylate (PCE) type of superplasticizer is incorporated into the design. The PCE superplasticizer that is utilized is Talrakplast PC3550 which is compatible with all types of cement. In order to determine optimum dosage of superplasticizer in cement mortar, mini slump cone test is conducted. The cement mortar was poured into the mould and allowed to flow. The percentage of superplasticizer was varied from 0%, 0.2%, 0.4%, 0.6%, 0.8% and 1% by weight of cement. It was observed that the optimum dosage of superplasticizer for cement mortar was determined to be 0.8%. To the GO cement mortars prepared as stated earlier, similar mixes are made by the addition of superplasticizer of 0.8%.

3.0 Results and Discussion

3.1 Compressive Strength

The compressive strength of cement mortar samples molded is determined for 7, 28 and 56 days. The tests are performed according to IS 3535:1986 on the standard Compressive Testing Machine (CTM). The result of the tests performed is as shown in the Figure 1. It was observed from the results that the compressive strength of the cement mortars prepared with M-Sand was greater than the mortar with R-Sand. The maximum compressive strength for R-Sand and M-Sand was observed at 0.02% and 0.06% of GO. The mortar prepared with M-Sand has more strength properties due to its roughness properties. There was about 17.025% and 19.032% increase in strength due to the addition of superplasticizer in R-Sand and M-Sand respectively.

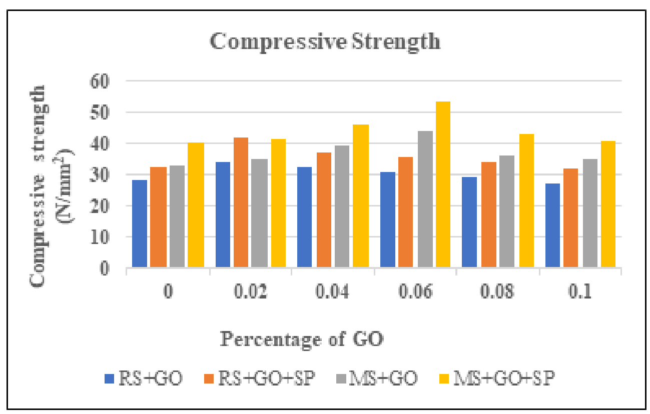

Figure 1. Compressive strength results.

3.2 Flexural Strength

The flexural strength test for the cement mortar is conducted in order to determine the resistance offered to the load applied on it. The was performed following guidelines from ASTM C380. The molds were casted for

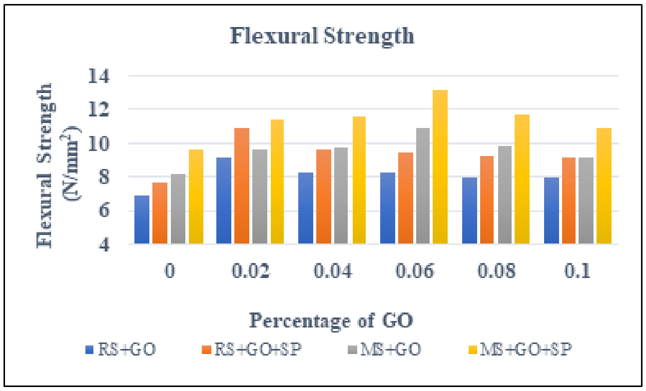

Figure 2. Flexural strength results.

0.4 x 0.4 x 0.6 mm size and allowed to cure for 28 days. The results obtained for the tests are as indicated in the Figure 2. It is noted that the maximum flexural strength for cement mortar prepared with R-Sand and M-Sand was obtained at 0.02% and 0.06% of addition of GO respectively. There is an increment of 15.66% and 19.132% in strength due to influence of superplasticizer in R-sand and M-sand respectively.

3.3 Microstructural Properties

The microstructural analysis of the cement mortar is carried out through Scanning Electron Microscope (SEM). The SEM analysis determines the cement paste and C-S-H bonding behavior in the mortar. Cement paste prepared with water cement ratio of 0.5 along with the optimum dosage of GO as determined from the previous tests which is 0.02% and 0.06% for R-sand and M-sand

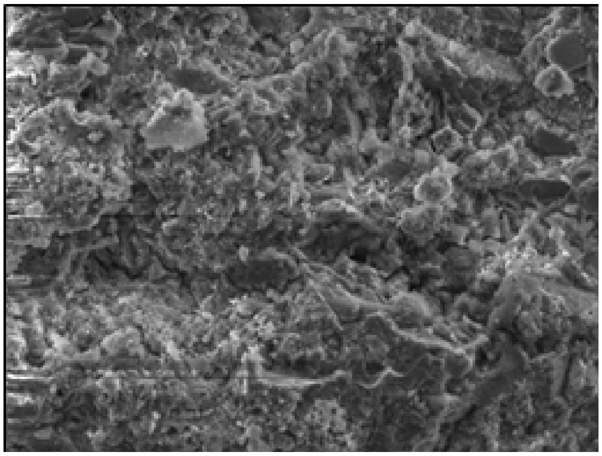

Figure 3. SEM image of normal mortar.

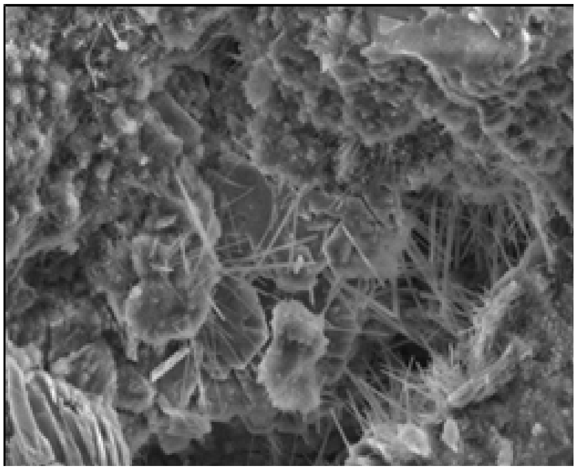

Figure 4. SEM image of Mortar + GO.

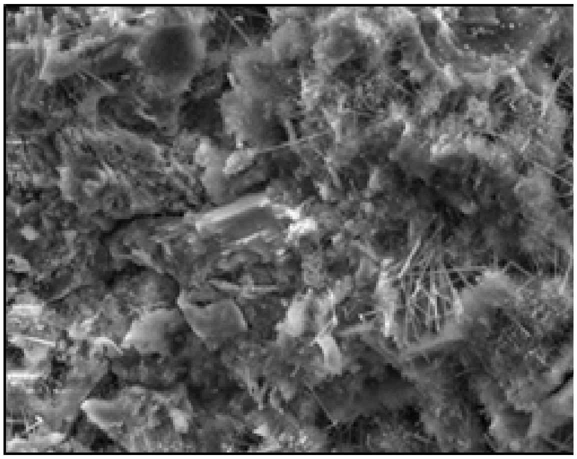

Figure 5. SEM image of Mortar + GO + SP.

respectively. The cement paste is cast into small cubes, which is allowed to dry for 2 days and then de-molded for curing, after curing the specimen for 7 and 28 days, it is prepared for SEM analysis. The analysis is carried out through VEGA3 TESCAN with the wavelength range of 5μm with a resolution of x 10000.

The SEM images of normal cement paste, cement paste + GO, and cement paste + GO + SP can be witnessed in Figures 3, 4 and 5 respectively. The floral-type images observed in Figure 1 indicate the cement and water interaction. Needle-like structures in Figure 2 specify the presence of GO particles. The shape of GO helps it to interlock the pores present between cement particles.

The existence of GO helps in the reduction of initiation and subsequent propagation of micro-cracks within the

Table 2. Composition of elements through EDX analysis

Element	Na_2O	MgO	Al_2O_3	SiO_2	SO_3	K_2O	CaO	Fe_2O_3
N (28 Days)	0.08	0.28	2.73	19.01	1.83	0.04	72.69	3.34
GO (7 Days)	0.18	0.05	2.37	16.94	2.05	0.06	74.89	3.46
GO+SP (7 days)	2.04	0.45	3.75	19.3	1.59	0.73	68.66	3.47
GO (28 Days)	0.31	0.29	3.39	20.9	1.82	0.01	70.13	3.14
GO+SP (28 Days)	1.69	0.23	2.08	16.34	1.49	0.82	73.47	3.88

structure. The intermolecular interaction between the particles observed in Figure 5 is packed compared to image in Figure 3 due to the addition of super plasticizer to the mix that in turn enhances the strength of the structure.

From the Table 2 it is evident the usage of superplasticizers has led to rise in Al_2O_3 and SiO_2 content. The increase in Al_2O_3 and SiO_2 indicates the increase in the strength parameters which has been discussed in sections 3.1 and 3.2. They also contribute to the initial strength development in the mortar.

4.0 Conclusion

In this paper, a detail study on comparison of cement mortar made with R-sand and M-sand is carried out. From the tests performed, these conclusions can be drawn:

- The compressive strength of mortar made with M-sand has improved strength compared to R-Sand. The extreme strength for cement mortar with GO was attained with 0.02% and 0.06% for R-sand and M-sand respectively for curing periods of 7, 28 and 56 days.
- The crushing strength of the cement mortar has increased by 17% and 19% since SP was added to R-sand and M-sand respectively.
- The results obtained for the bending strength of the mortars made with R-sand and M-sand are in a similar pattern as crushing strength for 7, 28 and 56 days.
- The intermolecular spacing and the arrangement of particles in the cement mortar can be observed in the SEM analysis.
- Through EDX analysis, the increment of Al_2O_3 and SiO_2 can be observed which justifies the improvement in the strength of mortar with addition of superplasticizer.

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