# AN EXPERIMENTAL STUDY ON INFLUENCE OF GRAPHENE OXIDE ON STRENGTH OF CEMENT- FLY ASH MORTAR

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**Abstract** - *Nanotechnology, a multidisciplinary science focusing on enhancing material properties at the atomic level, holds immense potential to overcome limitations in various scientific domains. While extensively utilized in material science and electronics, its application in civil engineering, particularly in improving concrete, remains relatively understudied. Concrete, a fundamental material in civil engineering, faces challenges in resisting tensile stresses due to inherent weaknesses in cement components. To address this issue, research explores leveraging nanoscale materials with unique properties, including enhanced tensile and flexural strength.*

*This study investigates the efficacy of graphene oxide (GO), a nanomaterial, in enhancing the strength of mortar against tension and bending stresses. GO offers advantages such as effective dispersion in water, facilitating its incorporation into cement matrices without forming agglomerates. By utilizing GO water dispersion as mix water, the cement components can be imbued with graphene oxide throughout the structure.*

*The research objective entails an extensive literature review on the impact of nanomaterials on cement mortar, focusing on the effect of graphene oxide on cement and fly ash mortar. Experimental findings demonstrate significant improvements in mortar strength performance with the incorporation of graphene oxide.*

***Key Words***: **Nanotechnology, Graphene oxide, Cement mortar, Tensile strength, Flexural strength, Material science, Civil engineering**

## 1.INTRODUCTION

Nano material modification of cement-based material is an active area of research at present. Still, when compared to other engineering field, concrete technology has been slow to catch the emerging enhancements through nano technology. This is mainly due to the lack of basic understanding of concrete at nano level and the risk factors involved in dispersion of nano materials uniformly in the cement matrix.

However, the recent developments of the experimental techniques available have facilitated to study the concrete at micro and nano levels. Many researches work suggest addition of suitable nano particles into concrete to alter many properties of concrete. As a part of project this section outlines the findings of few important works related to Graphene Oxide and its incorporation in cement phase.

A great number of researches have been performed to Understand the nature of nanomaterials and their effect on the properties of concrete. A comparative analysis of this work has been presented in the summary of this chapter which will highlight the significance of each work. Out of the numerous works done in the field only a few relevant works have been highlighted in the next section.

### 1.1 LITERATURE SUMMARY

From the work carried by the researchers on incorporation of nana materials into the cement mortar and concrete it can be concluded that different nana materials can be incorporated to improve the performance and strength properties of cement mortar and concrete. Few investigations were carried out on performance of mortar incorporating graphene oxide. Extensive research is needed to explore the possibility of incorporation of Graphene Oxide and study the performance and behavior of mortar and concrete.

### 1.2 OBJECTIVES

1. To explore how varying concentrations of graphene oxide impact the compressive strength, flexural strength, and tensile strength of concrete.

2. To assess the characteristics of cement-fly ash mortar with and without graphene oxide. Incorporating partial cement replacement with fly ash and complete sand replacement with M-sand in concrete is preferred due to advantages like improved workability, reduced cement usage, and decreased permeability.

## 2. METHODOLOGY

### 2.1 Procurement of Materials

Cement, sand, fly ash, and graphene oxide are procured from reliable sources. Basic tests are conducted on cement and sand to ensure quality:

### 2.1.1 Specific gravity test for cement

Specific gravity of cement -The specific gravity of fresh batch of OPC generally ranges between 3.1 to 3.18, when tested as per Le Chatelier's flask method specified in IS 403(11)1988. Test conducted on the cement used, gave out the value of specific gravity as 2.88, within the established range of value. In general, the specific gravity of cement is taken as 3.15.

### 2.1.2 Normal consistency test for cement

This helps in determining water content for other tests of setting time test, compressive strength test. Test was carried out as per IS 4031(4) using Vicat apparatus and the value water to be added for normal consistency (P), was recorded as 26% by weight of cement.

### 2.1.3 Initial and final setting time tests for cement

This test uses the water content of 0.85P as obtained in the consistency test and is done as per IS 4031(5). The specified setting time for 43 grade OPC as in IS 8112 should not be less than 30 minutes in case of initial set and not more than 600 minutes for final set. The recorded setting time for the cement used is 80 minutes for initial set and 250 minutes for final set, thus satisfied

### 2.1.4 Compressive strength test for sand

Strength test is carried out as per IS 4031(6). Mortar of cement to M-sand ratio 1:3 is adopted and casted in 70mm cube moulds as test specimens. Results of cement tests conducted have been presented

### 2.1.5 Sieve analysis for sand

**Table 1. Sieve analysis**

| Sieve size in mm | Weight retained in gm | Percentage of retained | Cumulative percent retained | Percent passing |
|---|---|---|---|---|
| 4.75 | 3 | 0.3 | 0.3 | 99.7 |
| 2.36 | 78 | 7.8 | 8.1 | 91.9 |
| 1.18 | 292 | 29.2 | 37.3 | 62.7 |
| 600 µ | 243 | 24.3 | 61.6 | 38.4 |
| 300 µ | 256 | 25.6 | 87.2 | 12.8 |
| 150µ | 106 | 10.6 | 97.8 | 2.2 |
| 75 µ | 18 | 1.8 | 99.6 | 0.4 |
| Pan | 4 | 0.4 | 100 | 0 |

## 2.2 Concrete mix Proportion

The mortar mix was proportioned for cement to sand part by weight, considering the minimum void% mix Calculated as per IS 2386(3)-1963.

The bulk density and specific gravity of different mortar mixes were calculated. Kerosene was used in finding out the specific gravity of mortar mix by pycnometer method

**Table 2. Dry mortar mix void %**

| Mortar mix | Specific Gravity, G | Density, γ (g/cc) | % void= (G- γ) G |
|---|---|---|---|
| 1:10 | 2.98 | 2.09 | 27.7 |
| 1:5 | 2.84 | 2.19 | 22.8 |
| 1:3 | 2.8 | 2.28 | 18.5 |
| 1:2:5 | 2.78 | 2.23 | 19.7 |
| 1:2 | 2.71 | 2.15 | 20.6 |

From the table it is observed that the mortar of cement to sand proportion-1:3 by weight, showed the least void percentage and the same was chosen as the test mortar mix proportion for subsequent studies.

## 2.3 Synthesis of Graphene Oxide (GO)

About 2g of powdered graphite is mixed with 100ml of concentrated H2SO4 at room temperature, serving as an oxidizing agent to make it hydrophilic. The mixture is then cooled to 5°C for 30 minutes. 8.0g of KMnO4 is slowly added while stirring and maintaining the temperature below 10°C. Next, 100ml of water is added and mixed for 1 hour, then diluted to 300ml. 20ml of 30% H2SO4 is added to reduce residual KMnO4. The solid is treated with 800ml of 5% HCl solution to remove metal ions and diluted with water to reach a pH of 6. The resulting Graphene oxide is dried at 45°C for 24 hours to obtain a nano-sized amorphous product.

Exfoliation of the bulk Graphene oxide in an ultrasonic bath with water yields a greyish-brown, semi-transparent dispersion. Finally, the Graphene oxide is reduced to mono-layered Graphene using a reductant such as Hydrazine, despite its high toxicity. The company limits the dispersion of Graphene oxide in water to a maximum of 5 grams per liter. Different dosages of Graphene oxide dispersed in 5 liters of water are as follows: 0.02% GO dispersion - 0.2 grams GO per liter. This suspension, used with a water-cement ratio of 0.7, provides the required quantity of GO for incorporation into cement mortar by weight percent of cement.

## 2.4 Mixing

To ensure thorough mixing and dispersion of Graphene Oxide, an electrically operated Hobart mixer meeting IS 2250-1981 standards should be used. Cement and sand must be mixed dry until a uniform color is achieved before adding water. The mixer's vanes should rotate while water is added, and mixing should continue for 3 to 5 minutes for optimal blending.

The nanocomposite preparation involves suspending graphene oxide in distilled water and sonicating for 3 hours until a homogeneous solution form. OPC is then added, maintaining a water-to-cement ratio of 0.5. Sand is

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added last. The cement mortar is then placed on smooth glass to prevent sample grinding.

Throughout the ripening process, samples should be stored in a humidity chamber at a constant temperature of 20°C.

### 2.5 Casting

Moulds were filled with at least 2 layers of mortar in case of smaller dimension moulds. Tamping done using a square headed light weight tamper rod by giving 25 blows uniformly all along the mortar surface for successive layers.Top layer is finished by giving smooth finish and allowed to set without disturbance for a day's duration before de-moulding.

**Fig 1: Cubes**

**Fig 2: Briquettes**

**Fig 3: Prism**

### 2.6 Demolding

Demoulding of Test Specimens should occur between 16 and 24 hours after creation. If the mortar hasn't gained enough strength for demoulding without damage, wait an additional 24 hours. When removing specimens, disassemble the mould completely to prevent damage. Use a waterproof crayon or ink to mark each specimen for identification after demoulding. Thoroughly clean the mould to prevent leakage and irregular shapes. Carefully demould specimens to avoid breakage and cure them for an adequate number of days before testing.

### 2.7 Curing of Specimens

It is mentioned in IS 456-2000, that a minimum curing period of 28 days has to be practiced in case of OPC used without any mineral admixtures. Curing periods should be adopted for 28 days testing of mortar. However, only compression test, flexure test and tensile test were carried out for on mortar cubes and briquettes respectively and the remaining tests are done just after 28 days of curing.

### 2.8 Testing of Specimens

Performed tests on the cured specimens to evaluate their fresh properties and strength characteristics

#### 2.8.1 Flow Test

Measuring the flow of mortar to assess workability. The free water to cement ratio was determined for 90 to 100% flow plain cement mortar when tested on flow table, as per IS 1199-1959.

#### 2.8.2 Compressive Strength Test

This test gives the amount of stress, which the mortar can resist before failure. It will be carried out in accordance with IS 2250-1981 as shown in 50 mm mould are used to cast mortar cubes as testing specimens. Curing period of 28 days are suggested to check for early strength development and later strength increments.

#### 2.8.3 Tensile Strength Test

Cement, as known is week in resisting tensile stresses due to its brittle nature. It is by this test where we can calculate the tensile strength of the cement component. Mortar briquettes of standard dimension specified in IS 4456(1)-1967 will be casted in suitable mould, and allowed to set for 24 hours before de-moulding. Then after the necessary curing period, the test specimens are tested against tensile stresses, with briquettes placed within a jaw holder test set-up

#### 2.8.4 Flexural Strength Test

Flexural strength (sometimes called the modulus of rupture) is actually a measure of tensile strength in bending. PCC flexural strength testing is carried out on a 40 x 40 x 160 mm (1.57-inch x 1.57-inch x 6.30-inch) cement mortar beam. The beam is then loaded at its center point until failure.

## 3.RESULT

The main result from the paragraph is that incorporating nanomaterials, specifically graphene oxide (GO), into cement mortar can significantly increase both compressive and tensile strength. Past research has shown up to a 27% increase in compressive strength and 3.7 times increase in tensile strength compared to traditional levels. This suggests that GO holds promise for enhancing the strength of cement mortar, potentially addressing issues related to microcrack development and improving the overall durability of concrete structures.

### 3.1 Compressive Strength

**Table 3: Compressive Strength Results**

| Sl no | Test | Age | Cement+ FA+ water + 0.02% graphene oxide ($N/mm^2$) | Cement FA+ water +30% fly ash+0.02% graphene oxide ($N/mm^2$) | Cement FA+ water+0.02% graphene oxide ($N/mm^2$) | Cement FA+ water+30% fly ash+ 0.02% graphene oxide ($N/mm^2$) |
|---|---|---|---|---|---|---|
| 1 | Compressive strength | $28^{th}$ day | 20.66 | 23.125 | 26.15 | 27.70 |
| 2 | | | 22.14 | 23.618 | 24.60 | 26.85 |
| 3 | | | 21.158 | 23.125 | 25.125 | 27.56 |

### 3.2 Tensile strength

**Table 4: Tensile Strength Results**

| Sl no | Test | Age | Cement+ FA+ water + 0.02% graphene oxide (N/mm²) | Cement FA+ water +30% fly ash+0.02% graphene oxide (N/mm²) | Cement FA+ water+0.02% graphene oxide (N/mm²) | Cement FA+ water+30% fly ash+ 0.02% graphene oxide (N/mm²) |
|---|---|---|---|---|---|---|
| 1 | Tensile strength | 28th day | 2.90 | 3.04 | 3.1 | 3.12 |
| 2 | | | 3.04 | 3.14 | 3.28 | 3.35 |
| 3 | | | 2.95 | 3.12 | 3.25 | 3.29 |

### 3.3 Flexural Strength

**Table 5: Flexure Strength Results**

| Sl no | Test | Age | Cement+ FA+ water + 0.02% graphene oxide (N/mm²) | Cement FA+ water +30% fly ash+0.02% graphene oxide (N/mm²) | Cement FA+ water+0.02% graphene oxide (N/mm²) | Cement FA+ water+30% fly ash+ 0.02% graphene oxide (N/mm²) |
|---|---|---|---|---|---|---|
| 1 | Flexural strength | 28th day | 4.55 | 5.3 | 6.9 | 7.63 |
| 2 | | | 4.6 | 5.095 | 7.27 | 7.9 |
| 3 | | | 4.45 | 5.195 | 7.32 | 8.05 |

## 4. CONCLUSION

Based on the experimental findings, the following conclusions can be made:

There was a notable increase in both concrete compressive strength and flexural strength during the early stages of hardening.

The addition of 30% fly ash resulted in an 11% increase in compressive strength, while the addition of 0.02% graphene oxide led to a 23% increase. Furthermore, combining 0.02% graphene oxide with 30% fly ash resulted in a 28% increase in compressive strength.

Fly ash had minimal impact on tensile strength. A 4.6% increase was observed with 30% fly ash, and an 8.44% increase was noted with 0.02% graphene oxide. Additionally, combining 0.02% graphene oxide with 30% fly ash led to a 9.89% increase in tensile strength.

Flexural strength saw a 15% increase with 30% fly ash and a substantial 58% increase with 0.02% graphene oxide. Moreover, combining 0.02% graphene oxide with 30% fly ash resulted in a remarkable 73.51% increase in flexural strength.

These findings suggest that graphene oxide shows promise as a material for enhancing the flexural strength of cement mortar, as indicated by the results of the present study.

### 4.1 SCOPE FOR FUTURE WORK

1. Influence of Graphene Oxide can be examined when incorporated into concrete mix. Compatibility with suitable super-plasticizer can be arrived at.
2. Combination of Pozzolanic materials such as Fly ash, silica fumes etc. with Graphene Oxide, can be analyzed for their impact on concrete properties.
3. The use of graphene oxide has the potential to deliver stronger, less permeable concrete structures enabling a new generation of concrete designs.
4. 3D graphene new material, sponge like configuration with density of just 5%, can have strength 10times that of steel

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