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Experimental Investigation on Graphene oxide Composites with Fly Ash Concrete

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Abstract: As the consumption of concrete increases, the world production of cement is continuing and grew to a significant amount. Portland cement production is a highly energy intensive process, and emits CO_2 during calcinations which has a crucial effect on global warming. The production of one tone of ordinary Portland cement (OPC) releases approximately one tonne of carbon dioxide to the atmosphere. Scarcity of Natural River sand because of environmental condition. It is necessary to replace natural sand in concrete by an alternate material partially, without compromising the quality of concrete. Adding partial replacement on cement with fly ash and complete replacement of sand with M- sand in concrete is desirable because of benefits such as increased workability, reduction of cement consumption and decreased permeability and useful disposal of a byproduct, reduction of river sand consumption and increased strength respectively. The incorporation of flyash as partial replacement of cement in concrete and is a common practice and along with that the use of nano particles has received particular attention in the application of construction materials especially in cement mortar and concrete. The application of nanomaterials in construction is a new alternative to enhance the mechanical properties of the concretes. One of the most interesting nanomaterials which still require detailed investigation is graphene and graphene oxide. The study presented in this paper aims at assessing how 0.03 to 0.11 wt% of graphene oxide incorporated into the cement can affect the physical–mechanical properties of the cement composite in fly ash concrete. The flexural behavior of graphene oxide fly ash concrete in structural member (beam) is investigated with the optimal percentage (0.03%) that is obtained from the mechanical strength studies. Flexural strength of beam is studied by applying two points loading.

Keywords: *Cement, Nanocomposite, Graphene Oxide, Fly Ash, M Sand, Superplasticizer, Compressive strength, Tensile Strength*

1. Introduction

Concrete is the most widely used construction material in the world. It is composed of cement paste, aggregates and pores [1]. The concrete industry is constantly looking for supplementary cementitious material with the objective of reducing the solid waste disposal problems i.e Fly Ash (FA) are among the solid wastes generated by industry. Substantial energy and cost savings can result when industrial by - products are used as partial replacements for the energy intensive Portland cement. High quality sand is in short supply in India thus; an increased demand for concrete can be met by replacing natural sand with M - sand. The detailed experimental investigation is came to study the effect of the feasibility of using partial replacement of cement by Fly Ash (FA) and full replacement of fine aggregate by M sand with using admixture in concrete [2]. Progress in the field of nanomaterials presents invaluable opportunities to further raise the performance bar with the inclusion nanomaterials in cementitious composites. There have been many recent studies on newly produced nanomaterials in cement composites such as nanosilica, nanotitanium oxide, carbon nanotubes (CNTs), graphene oxide etc., In the past years, graphene and its derivatives have been investigated extensively, The superlative properties of graphene oxide has a promising future when combined with ordinary Portland cement (OPC), forming a nanocomposite with fly ash concrete [3].

2. Material Properties

2.1 Cement

Ordinary Portland Cement (43 Grade) confirming to IS:8112-1989 was used. It should be free from lumps. The physical properties of cement are shown in Table 1.

Table 1.*Physical Properties of Cement*

Characteristics	Value
Specific gravity	3.15
Consistency	30%
Initial setting time	90 mins
Final setting time	178 mins

2.2 Fly Ash

Fly ash is finely divided residue resulting from the combustion of ground or powered coal. The partial replacement of cement with fly ash reduces the production cost of concrete due to the lower price of fly ash compared to cement. Fly ash contains less than

20% lime is collected from Mettur Thermal Power Plant (MTTP), Mettur.

Table 2.*Physical Properties of Fly ash*

Characteristics	Values
Class	F
Specific gravity	1.145.

2.3 Coarse Aggregate

Coarse aggregate are produced by disintegration of rocks and by crushing rocks. These are available in different sizes. Coarse aggregate are usually those particles which are restrained on IS 4.75mm sieve. Coarse aggregate used in this study were 20 mm nominal size and tested as per Indian standard specification IS:383 – 1970.

Table 3 *Physical Properties of Coarse Aggregate*

Characteristics	Value
Type	Crushed
Maximum size	20mm
Specific gravity	2.68
Fineness modulus	7.07

2.4 Fine Aggregate (M-Sand)

Fine aggregate is an important and essential ingredient of concrete. The M sand product from plant is of a consistent high quality and has good equi dimensional shape. The crusher sand used for the experimental programmed was locally procured and conformed to grading zone II. The fine aggregates were tested per Indian Standard Specifications IS: 383-1970.

Table 4 *Physical Properties of Fine Aggregate*

Characteristics	Value
Type	Crushed
Maximum size	4.75mm
Specific gravity	2.65
Fineness modulus	2.68

2.5 Superplasticizer

Commercially available Super-plasticiser CONPLAST SP 430, based on Sulphanated naphthalene polymers, complies with IS 9103-1999. It used as a water-reducing admixture has been used to enhance the workability of fresh concrete for selected proportions of ingredients.

Table 5 *Physical Properties of Superplasticizer*

Characteristics	Value
Appearance	Brown Liquid
Specific gravity	1.145

2.6 Graphene Oxide

Graphene is defined as a single layer of carbon atoms arranged in a hexagonal lattice. Graphene, a “wonder material” is the world’s thinnest, strongest, and stiffest material. It is the basic building block of other important allotropes. Graphene is considered as the fundamental building block for graphitic materials of all other dimensions.

Table 6 *Physical Properties of Graphene Oxide*

Characteristics	Value
Physical state and appearance	Solid
Odor	Odorless
Taste	Tasteless
Molecular Weight	12.01 g/mole
Color	Yellow or Black

2.6.1 Preparation of Graphene Oxide

Graphite flakes (0.5 g) and $NaNO_3$ (0.5 g) were mixed in 23 mL of conc. H_2SO_4 in a 50 ml volumetric flask kept under at ice bath (20ºC) with continuous stirring. The mixture was stirred for 4 hrs at this temperature and potassium permanganate (3 g) was added to the suspension very slowly. The rate of addition was carefully controlled to keep the reaction temperature lower than 15ºC (increase in temperature results in explosion). The mixture is diluted with very slow addition of 46 ml distilled water and kept under stirring for 2 hrs. The ice bath was then removed, and the mixture was stirred at 35°C for 2 hrs. The above mixture is kept in a oven at 90-95°C for 2 hrs. don’t let the mixture to boil After 10 min, change the temperature to 20°C which gives brown colored solution and maintain it. The solution is finally treated with 10 ml H_2O_2 (30 %) solution. 200 ml of water is taken in two separate beakers and equal amount of solution prepared is added and stirred for few mins. It is then kept without disturbed, where the particles settles at the bottom and remaining water is poured to filter. The resulting mixture is washed by centrifugation with 5% HCl and then with distilled (DI) water (pH-7 neutral). The graphene oxide solution is thus formed. Graphene oxide is synthesis by using modified hummers method is shown in fig 1.

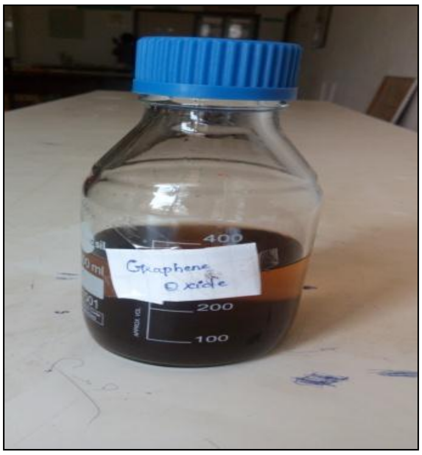

Fig 1 *Graphene Oxide*

2.7 Water

The water, which is used for making concrete, should be clean and free from harmful impurities such as oil, alkali, acid, etc., Locally available potable tap water is used for casting.

3. Mix Design

Mix design is the process of selecting suitable ingredient if concrete and determines their relative proportions with the object of certain minimum strength as economically as possible. Design procedure was formulated for fly ash concrete which was relevant to Indian standard (IS 10262-2009). The illustrative mix design for a fly ash concrete of M25 grade.

Table 7 *Mix Proportions*

All are in kg/m^3	Mix 1	Mix 2	Mix 3	Mix 4
GO (%)	0	0.03	0.07	0.11
Cement	196	195.94	195.86	195.78
Fly ash	103	103	103	103
GO	0	0.06	0.14	0.22
FA	588	587.82	587.58	587.34
CA	1216.3	1216.3	1216.3	1216.3
Additive	1.72	1.72	1.72	1.72
W/C	0.41	0.41	0.41	0.41
Water	80.36	80.34	80.3	80.27

4. Experimental Investigation

In this investigation the fresh and hardened properties of Fly Ash concrete for replacement 30% of Fly ash, 0.03-0.11 wt% of graphene oxide and full replacement of M- sand are determined.

4.1 Fresh concrete results

4.1.1 Slump cone test

It is used to determine the workability of fresh concrete. The apparatus used for slump test are: slump cone and tamping rod.

Table 8 *slump cone test results*

GO %	0 mins	30 mins
0	90	80
0.03	58	52
0.07	65	60
0.11	70	67

Fig 2 *slump cone*

4.2 Hardened Properties

In order to find the mechanical properties, Compressive strength and split tensile strength , cube (150 X 150 X 150 mm) and cylinder (100 mm dia X 200 mm hgt) specimen are to be casted for 3,7 and 28days of curing respectively. For each combination, two specimens were tested. The test results are discussed in the following Tables.

4.2.1 Compressive Strength

Table 9 *Compressive strength*

Mix	GO %	Average Compressive Strength (Mpa)		
		3rd day	7th day	28th day
M 1	0	15.75	21.00	24.60
M 2	0.03	17.8	28	36
M 3	0.07	14.8	20.8	30.6
M 4	0.11	14	20	25

Fig 3 *Compressive Test*

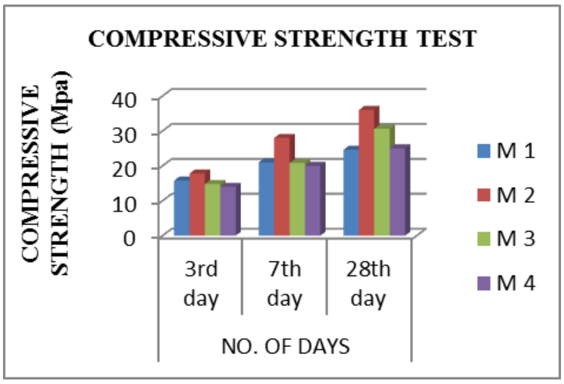

Fig 4.*Compressive Test Graph*

4.2.2 Split Tensile Strength

Table 10 *Split Tensile Strength*

Mix	GO %	Average split tensile Strength (Mpa)		
		3rd day	7th day	28th day
M 1	0	2.4	2.8	3.15
M 2	0.03	2.86	3.18	3.82
M 3	0.07	2.546	3.15	3.5
M 4	0.11	2.85	3.05	3.6

Fig 5.Split tensile test

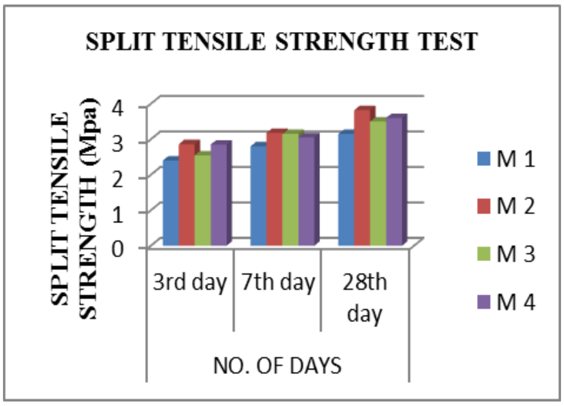

Fig 6.Split Tensile Strength Graph

5. Flexure Beam

From the results of mechanical strength it is summerized that the optimum percentage of graphene oxide (0.03%) improves the strength of concrete. Hence beam is casted for an optimal percentage of 0.03 wt % of cement in fly ash concrete. The beam is casted and cured for the period of 3,7 and 28 days. The beam is tested by applying Two-point loading.

***Table 11** flexural strength*

Mix	GO %	Average Flexural Strength(Mpa)		
		3rd day	7th day	28th day
M 1	0	3.80	4.27	4.71
M 2	0.03	3.96	4.45	4.82

Fig 7.Flexure beam

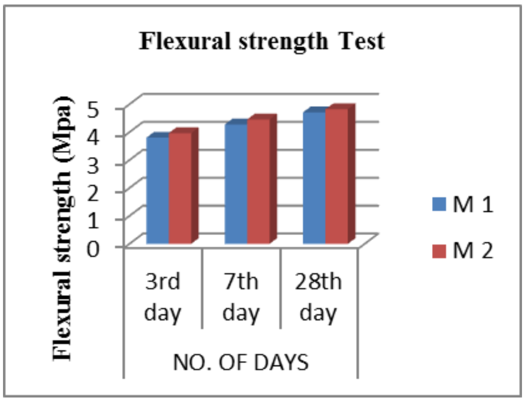

Fig 8 flexural strength graph

Load Deflection for Flexure Beams

***Table 12** Load vs Deflection Test Results for Flexure Beams*

M1		M2	
Load (kN)	Deflection (mm)	Load (kN)	Deflection (mm)
0	0	0	0
10	0.15	10	0.13
20	0.35	20	0.35
30	2.5	30	3
40	4	40	3.9
50	4.8	50	4.75
60	7.5	60	7.5
70	10.3	70	10.28
80	14	80	13.9
85	18.5	88	18.4
75	24	85	23

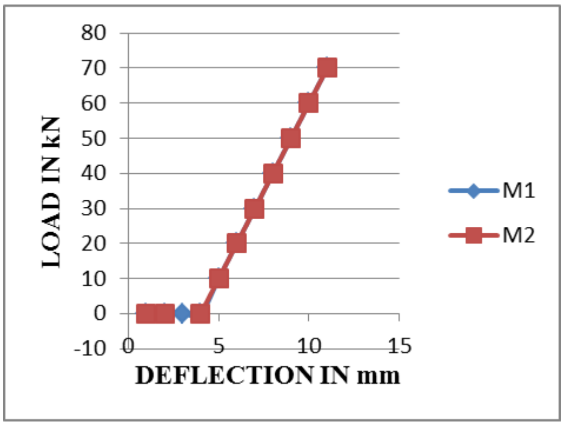

Fig 9Comparison of Load Deflection Curve Plot For Various Mixes

6. Conclusion

Addition of graphene oxide increases the strength of concrete. The use of fly ash influences the physio chemical effects associated with pozzolanic and cementitious and grain size reduction phenomena. The most important aspect followed in the project is to reduce the environmental hazards by using waste materials in concrete. The addition of GO improves the degree of hydration of the cement paste and increases the density of the cement matrix, creating a more durable product. The addition of GO can lead to a reduction in workability of the cement paste. Further studies are needed to improve the workability of fresh GO–cement composites. Flexural behavior of reinforced concrete beam is evaluated for flexural strength at 28 days.

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