COMPARATIVE STUDY ON PERFORMANCE OF CONCRETE ENHANCED WITH GRAPHENE COMPOUND

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ABSTRACT

The new dimension in the construction world is nanotechnology. The development in the field of nanotechnology gives an advantage of developing cementitious materials at nanoscale. In the present study, an attempt is made to use this technology in concrete. This experimental work is completely based on nano technology and came up with the idea of introducing nanoparticles in the raw materials used for construction. Nano materials are available in three principal shapes 0D, 1D and 2D nanoparticles. 0D and 1D nanofibers are such as carbon nanotubes and nanosilica compounds. This study investigates the properties of graphene and its applicability in construction i.e. in cement based mortar and concrete. Graphene is available in different forms like 0D, 1D and 2D. Graphene has created interest as it is believed to improve the strength of concrete allowing the possibility of controlling properties of concrete. In this work graphene is used as a reinforcing additive in cement based mortar and concrete. Graphene compound is prepared by using conventional graphite and concentrated hydrogen peroxide due to the unavailability of graphene. As a part of investigation, specific gravity and particle size distribution of graphene is studied in the laboratory. Then the compound is replaced as a part of small percentage in cement mortar cubes casted for various proportions. The mechanical properties of cement-based composites are studied after incorporating graphene compound in low dosages.

Keywords: Graphite, Graphene, Cement, Fine aggregate, Coarse aggregate Compressive Strength

INTRODUCTION

The nanotechnology has moved the world in all aspects. The use of nano particles in construction materials is another innovative move. This introduces the physical, chemical and mechanical properties of nanoparticles. A microscopic level of study is required to be done on the factors affecting the mechanical properties of concrete between the reactive paste and inert aggregates. Inertness is permeable to air and water properties which has greater impact on strength and durability of concrete structures. In the present study, an attempt is made to use this nano technology in concrete. This research work is done in a perspective that if use of nanoparticles in concrete could reduce the porous nature of concrete, improve the compressive strength of concrete and make it more durable. The graphene is chemically composed of carbon, oxygen and hydrogen, a three-dimensional structure composed of millions of layers of graphite [11]. The preparation of graphene material is discussed and its properties are studied. Graphite layers are exfoliated in layers to produce graphene. Graphene is available in different forms like 0D, 1D and 2D. Graphene is nothing but an allotrope of graphene. It is made from graphite powder. Graphite is exfoliated in layers to produce graphene. Graphene has proven to be the strongest material even tougher than diamond. The elastic module of graphene is around 1000 MPa. Hence, this research is a trail to impart its

strength to concrete. This material is rarely available in India.

The procedure for the preparation of graphene compound is arrived by referring the literature. Graphite is mixed with concentrated hydrogen peroxide in equal proportions. There is an exothermic reaction liberating vapours which measure a temperature of 110 to 120 ^{0} C. The vapours are cooled down and then the graphene compound is produced. Firstly, this compound is tried in cement by replacing cement at various proportions like 1%, 2% ,3%, 4% and 5% replacement. For the same proportions mortar cubes are casted and cured for 28 days. The compressive strengths obtained are compared with conventional mortar cube strengths. Concrete cubes are casted by replacing cement with graphene compound by 5%. They are cured for 28 days and tested for compressive strength. They are compared with conventional concrete cubes.

MATERIALS AND METHODS:

The materials used in this experimental work are Ordinary Portland Cement (53grade), Coarse Aggregate of 10mm size, Fine Aggregate of Zone-II and potable Water.

a) Cement: properties of cement are listed in table 1

Ordinary Portland cement of 53 grade of a single lot is used throughout the investigation.

Physical properties of cement have been compared with the requirements of IS: 12269:2013.

All the required tests on cement are carried out as per recommendation of IS: 4031-1988. Care has been taken while preserving the cement in a store with air tight condition to prevent it from moisture, humidity.

Property	Units	Value Obtained	Limiting value as per IS:12269: 2013 Specifications
Specific gravity	—	3.05	—
Normal consistency	%	25.5	<30
Settin g time			
Initial	Minutes	45	30
Final	Minutes	550	600 (max)

Table 1: Properties of cement

b) Fine aggregate: properties of fine aggregates are listed in table 2.

Locally available river sand is used as fine aggregate in this investigation. The sand has clay, silt and other impurities. The result of sieve analysis is shown in Table. Based on the particle size fine aggregate comes under Zone-II of IS 383- 1970. Fineness modulus of fine aggregate is 2.98.

IS sieve size	Weight retained (grm)	Percentage Weight retained (grm)	Cumulative % Weight Retained	Percentage Weight passing	IS 383-1970specifications of % passing for Zone II
10 mm	0	0	0	100	100
4.75 mm	150	5	5	95	90-100
2.36 mm	300	10	15	85	75-100
1.18 mm	800	26.6	41.6	60.34	55-90
600 µ	788	26.33	66.6	36	35-59
300 µ	700	24.34	89.94	9.65	42246
150 µ	232	7.73	98.61	1	0-10
Pan	30	1	100	0	0

Table 2: Sieve Analysis of Fine Aggregate

c) Coarse aggregate: properties of coarse aggregates are listed in table 3.

Locally available 10mm coarse aggregate is used in this investigation. It is free from impurities like dust, clay particles and organic matter. The results of sieve analysis are shown in Table 3. The fineness modulus of coarse aggregate is 6.26.

IS sieve size	Weight retained(kg)	% Weight Retained	Cumulative % Weight retained	Percentage Weight Passing	IS 383-1970specifications for % passing
12.5	0.21	5.37	5.37	94.63	90-100
10mm	1.0	25.57	30.95	69.05	40-85
4.75 mm	2.33	59.60	90.54	9.46	0-10
Residue	0.37	9.46	100	0	—

Table 3: Sieve Analysis of Coarse Aggregate

The physical properties of fine and coarse aggregates are shown in table 4.

Characteristics	Results Obtained	
	Fine Aggregate	Coarse Aggregate
Grading	Zone II (IS:383-1970)	_
Fineness Modulus	2.98	6.26
Specific Gravity	2.64	2.67
Density (loose) Kn/m3	15.23	16.19
Water Absorption (%)	1.2	0.6
Moisture Content (%)	0.35	Nil

Table 4: Physical Properties of Fine and Coarse Aggregate

d) Water

Water is used for both the mixing of concrete and curing of beam and cube Specimens in present investigation. Water is free from deleterious materials. Curing of all the specimens were done by immersing in curing tanks by frequent change in water.

Procedure for preparation of graphene compound:

- Graphite powder is taken as input product.
- 50% conc.H_2O_2 is used as reactant.
- A few amounts of conc.H_2O_2 is taken in a glass jar.
- Graphite powder is added in a proportion of 1:1.
- The mixture is stirred well to initiate the reaction.
- Then an exothermic reaction could be observed.
- Emitting vapours and liberating heat measures up to temperature of 110^0c to 120^0c
- This is continued until the reaction starts retarding.
- Then it is oven dried and the powder is collected.
- This drying process lasts for 15-20 minutes

Methodology adopted for performing the compression strength test:

1. The compressive strength tests on mortar cubes of size (70.7mm X

70.7mm X 70.7mm) conducted as per Code of Practice IS: 4031 – (Part-6)

2. The compressive tests on concrete Specimens prepared are conducted as per code of practice IS:516 - 1959. The typical blocks are (150 x 150 x 150mm) cubes.

Experimental Program

- Three conventional cement mortar cubes are casted with cement, sand and water as per Code of Practice IS: 4031 – (Part-6), and they are cured for 28 days.
- These mortar cubes are tested in the compression testing machine as per Indian Standard code of practice.
- 15 Mortar cubes are casted by replacing cement with graphene compound in the proportions of 1%,2%,3%,4% and 5%, and they are cured for 28 days.
- These mortar cubes are tested in the compression testing machine as per Indian Standard code of practice.
- The results are compared with that of the conventional mortar cubes results.
- 3 conventional concrete cubes of nominal mix (1:2:4) of size 150mmx150mmx150mm are casted as per code of practice IS:516 – 1959, and they are cured for 28 days.
- They are tested in the compression testing machine as per Indian Standard code of practice.
- 3 concrete cubes are casted by above mentioned mix with replacing cement with graphene compound by a proportion of 5%, and they are cured for 28 days.
- They are tested in the compression testing machine as per Indian Standard code of practice.
- The results are compared with the conventional mortar cubes results.

RESULTS AND DISCUSSIONS:

Different combination of mixes tried by replacing various proportions of cement with graphene such as 1%, 2%, 3%, 4%, and 5% and mortar cubes are casted. They are listed down in the table 5 and the corresponding compressive strengths of various mixes are noted down. Their compressive strengths are compared with compressive strength of conventional mortar cubes.

S. No	Types of mix	Replacement percentage	Peak load(kN)	Stress(N/mm^2)	Avg. Stress (N/mm^2)
1	M1	Conventional	237.4 234.9 242.4	45.1 43.9 47.2	45.4
2	M2	Graphene [5%]	249.4 252.4 256.9	49.9 50.5 51.4	50.6
3	M3	Graphene [4%]	242.9 245.9 247.4	48.6 49.2 49.5	49.1
4	M4	Graphene [3%]	244.4 242.9 241.4	48.9 48.6 48.3	48.6
5	M5	Graphene [2%]	234.4 239.4 232.4	46.9 47.9 46.5	47.1
6	M6	Graphene [1%]	229.4 230.9 235.4	45.9 46.2 47.1	46.4

Table 5: Compressive strength results for mortar cubes at 28 days

Three concrete cubes are casted for nominal mix of (1:2:4) by replacing cement with graphene compound by a proportion of 5%. The compressive strength values are given in table 6 and are compared with the conventional cube strength results.

S. No	Types of mix	Replacement percentage	Peak load(kN)	Stress(N/mm^2)	Avg. Stress (N/mm^2)
1	CM1	Conventional	659.7 556.0 686.2	29.3 24.1 30.4	27.9
2	CM2	Graphene [5%]	826.4 813.2 835.1	36.7 36.0 37.2	36.6

Table 6: Compressive strength results for concrete cubes at 28 days

Mortar cubes of graphene compound showed a slight increase in compressive strength when compared to conventional mortar cubes from table-5 as mentioned. Concrete cubes of graphene compound showed a remarkable improvement when compared to conventional concrete cubes for a proportion of replacement by 5% with cement as shown in table-6.

CONCLUSION

1. A slight increase in compressive strength is observed using grapheme when compared to conventional mortar cubes.
2. Concrete cubes made with graphene compound showed improvement even up to 25% when compared to conventional concrete cube strength for a proportional replacement by 5% with cement.

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