Comparative Study on Flyash GGBS based Geopolymer Concrete using Graphene

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Abstract*: *Now a days concrete is the most commonly used material in the construction. This project evaluates the usage of graphene in the geopolymer concrete. The material used is graphene, which is a carbon allotrope and is the basic structural element present in graphite, coal and carbon nanotubes. The graphene has peculiar properties and it is 200 times stronger than steel. Graphene is added in proportion 0.005 to the percentage of geopolymer concrete, in order to study the geopolymer concrete behaviour to graphene content

Keywords: Graphene, Fly ash, GGBS, compressive strength and,durability

I. INTRODUCTION

The concrete industry faces challenges to meet the growing demand of Portland cement due to limited reserves of limestone, slow manufacturing growth and increasing carbon taxes. It is reported that the requirement of cement in India is likely to touch 550 million tonnes by 2020 with a shortfall of 230 million tonnes (58%) and the demand for cement has been constantly increasing due to increased infra-structural activities of the country. The geopolymer concrete is the alternative to meet the demands of future as GPC is cement free concrete. Geopolymer concrete.

Geopolymer is considered as the third generation cement after lime and ordinary Portland cement. The term ‘‘geopolymer’’ is generically used to describe a amorphous alkali.

Graphene is an allotrope of carbon in in the form of a two-dimensional, atomic-scale, hexagonal lattice in which one atom forms each vertex. It is the basic structural element of other allotropes, including graphite, charcoal, carbon nanotubes and fullerenes. It can be considered as an indefinitely large aromatic molecule.

Research grade grapheme is used and the details are as follows .

Technical details	
Carbon purity	> 99%.
Bulk density	0.25g/cc.
Number of layers	6
Surface area	150m /g^2
Tensile strength	>5GPA

Structural applications of graphene :

- Significant enhancement of the compressive and tensile strengths of concrete.
- Improved durability due to finer pore structure of the composites.
- Addition of graphene improves corrosion resistance of concrete.
- High strength and high ductility concrete that will resist extreme conditions.
- Graphene improves blast/fire and impact resistance of the concrete.

Objective

The main objective is to study the properties of geopolymer concrete when the graphene of 0.03 percentage of total weight of geopolymer concrete.

To enhance the strength properties of normal geopolymer concrete.

To study the behavior of geopolymer concrete after the addition of graphene by comparing with the normal geo polymer concrete..

Material Properties

(a)GGBS:

The ground granulated blast furnace slag (GGBS) is a leftover from steel manufacturing industries. It delays setting time of cement and the compressive and tensile properties of ggbs concrete is more than normal concrete. The ggbs provides pore refinement and GGBS reduces alkali-aggregate reaction when aggregate used in concrete are alkali reactive. production from harvesting to refining they use steel. Steel pipes are seamless welded to improve its strength properties.

(b)Fly ash: The fly ash used belongs to class F category. Fly ash is a waste generated by thermal power plants which improves compressive strength of concrete and also decreases permeability and cost. Fly ash in concrete makes it sulphate resistant.

CHEMICAL COMPOSITION		
Parameters (mass)	**Class F fly ash**	**GGBS**
Silica	50	37.73
Alumina	25	14.42
Ferrous oxide	10	1.11
Calcium oxide	1	3734

(c) Alkali activated solution:

Alkaline activator solution mainly consists of soluble alkalis that are usually of sodium or potassium based.

(d) Sodium hydroxide (NaOH) in combination with sodium silicate (Na 2SiO 3) is the commonly used in making GPC

(e) Graphene oxide: It’s available in powder and liquid form and the graphene oxide we used is in powder form.

Generic description	
Physical form	fluffy, very light powder
Color	grey black
Chemical formula	C

(f) Coarse Aggregate (Passing through 20 mm IS sieve).
(g) Fine Aggregate (Passing through 4.75mm IS sieve).

II. LITERATURE REVIEW

M. Devasena, J. Karthikeyan[1] presents optimum quantity of graphene oxide required to achieve maximum compressive, tensile and flexural strength of concrete. Graphene oxide was added to the concrete in three mix proportions. Graphene oxide content were varied by 0.05%, 0.1%, 0.2% of cement content.

Rangarajan [2] discussed about the comparative study on strength characteristics of Geo polymer concrete(GPC) and he states that the strength characteristics varies in different exposure conditions and explained that GPC cured at temperature of 60ºC at 24 hours, acquires strength at its initial stages and the full strength is achieved by ambient curing.

Mustafa [3] researched about the processing characterization and properties of flyash based geopolymer concrete and observed that the ratio of fly ash to alkaline activator is equal 2.0 and Na2SiO3 to NaOH ratio 2.5 is better for high compressive strength of 71 MPA which attains by using 16 molar NaOH solution, and also observed that the weight loss due to acidic exposure is 0.5 % compare to normal concrete and it doesn't shows any colour change even after 18 weeks still it is in contact with acid .

Kelli Ramjet[4] developed the low calcium flyash based Geopolymer concrete and proposed that strength parameters of the GPC can be varied by using different mixtures and prepared M40 grade concrete and founded that 0.40 alkaline to fly ash ratio and 0.21% of water binder ratio is suggested and the strength achieved at 28 days for GPC under ambient curing is also not equal to 7 day strength and from the results he recommended that 16 molar NAOH is better in attaining good strength.

Raijwala and Patel [5] done his work on a green concrete- Geo polymer in which low calcium class A fly ash is used and made a trail mix of 25 grade and casted cubes of standard size 150 X 150 X 150mm and cured at 250ºC and 600ºC for 24 hours. And observed that compressive strength increases are controlled by 1.5 times i.e. M25 grade achieves M45 strength and also observed that the weight loss in durability test is 10 times than that of the ordinary Portland cement concrete and recommended that GPC is better for severe environmental conditions.

Diaz and Allouche[6] work on recycling of fly ash into geo polymer concrete he developed the concrete by collecting several samples of fly ash from several fly ash sources by evaluating through X-RAY diffraction and particle size distribution and he developed concrete using different samples and casted cubes of M25 grade and cured for 3 days at 60ºC and cooled down to room temperature for 24 hours , and he prior to testing through X-RAY diffraction and found that the molecules are arranged without any molecular pattern are easy to dissolve and recombine as Geo polymer.

Janani & Revathi [7] developed the Geo polymer concrete using M-sand. showed that comparison of compressive strength of GPC between M-sand and river sand , and also prepared different mixtures of GPC by varying percentage of Msand like 40%, 60%, 80%, 100% and cured at 60ºC for 3 days and from the results concluded that 9% increase in the compressive strength when 100% replacement of M-sand with river sand and 12% increase in the tensile strength when 100% replacement with M- sand and 10% increase in the flexural strength of GPC by 100% replacement with M-sand and finally concluded that with the use of M-sand we can reduce environmental issues produced by OPC and make it a green concrete.

Silva & Sagoecrenstil [8] studied the amount of available aluminium for Geopolymerization plays a dominant role in controlling the setting time by increasing SiO2/Al2O3 leads to longer setting time, when these ratios are in the range of 3.48-3.8 is largely responsible for gaining high strength concrete at later stages but a corresponding ratio increase in aluminum leads to low strength which are accompanied by the micro structures when there is increase in NaAl-Si gain greater strength in these Geo polymers

III Mix design

The mix design of geopolymer concrete is to different when compared with conventional concrete. For this study, three mixtures with different Molarities 8M, 10M, 12M and fixed value of fly ash content 50% and GGBS content as 50%. The water to geopolymer solids (W/G) ratio by mass for all the mixes was maintained at 0.40 and the total powder content was fixed at 430 kg/m3. a water content of 10% of binder content. The alkaline solution-to-Binder ratio was kept 0.46 whereas the ratio of sodium silicate to sodium hydroxide concentration of 2.5 and respectively. Graphene of concentration and 0.005 percentage to that of total weight of binder content in geopolymer concrete. Preparation of NaOH Solution

To prepare sodium hydroxide solution, NaOH solids were dissolved in ordinary drinking water for 24 hours before we start the experiment and the prepared solution should be used within the time.

Sodium silicate solution obtained from chemical stores. In present investigation the ratio between sodium hydroxide and sodium silicate is taken as 1:2.5.

ALKALINE LIQUID

Generally alkaline liquids are prepared by mixing of NaOH solution and sodium silicate at the room temperature. When the solutions are mixed together then there will be reaction with each other there and polymerization take place. It liberate large amount of heat so it is recommended to leave it for about 20 minutes thus the alkaline liquid is ready as binding agent.

MOLARITY CALCULATION

The solids must be dissolved in water to make a solution with the required concentration. The concentration of sodium hydroxide solution can vary in different molar. The weight of NaOH solids in the solution depends on the concentration of the solution. NaOH solution with a concentration of 8 molar consist of 8x40 = 320grams of NaOH solids per litre of water, similarly for 10Molar consists of 10x40 = 400grams of NaOH solids and for 12Molar consists of 12x40 = 480grams of NaOH solids, were 40 is the molecular weight of NaOH. This amount of NaOH solids (pellets) are added in one litre of water for different molar concentrations.

S.No	Material	Quantity (Kgs/cubic meter)
1	Coarse Aggregate	790
2	Fine Aggregate	650
3	Fly Ash	215
4	GGBS	215
5	Sodium Hydroxide	50(8M,10M,12M)
6	Sodium silicate	125
7	Extra water content	10%binder
8	Na_2SiO_3/NaOH	2.5
9	W/G	0.4
10	Alkaline solution/Binder	0.45

IV.RESULT AND GRAPHS

A. Compressive strength testing

When it comes to strength the concrete is generally tested for compressive strength under UTM (universal testing machine).

FIG.1 UTM (universal testing machine).

The procedure to test the specimens are as follows.

1)The sodium hydroxide and sodium silicate are weighed depending on the molarity adopted

2)The graphene is replaced to about 0.005 percentage to the weight of binder content..

3)The fine aggregates along with coarse aggregate are mixed with binder content based on mix proportions to obtain M40 mix design.

4) Sodium hydroxide and sodium silicate are added to mix.

5) Water is added to above mix to obtain good workability.

6) In the case of graphene geopolymer concrete graphene in powder form is mixed with water taken in the mix design.

7) The cubes are left for curing for about 28 days , and the compressive strength is measured using UTM machine

The compressive strength of ordinary geopolymer concrete and graphene geopolymer concrete is noted for cubes subjected to curing for 28 days.

The compressive strength result's for **8M**(Molarity) geopolymer concrete(GPC) and graphene geopolymer concrete(GGPC)

Compressive strength in N/mm^2 for 28 days			
Specimens	S1	S2	S3
Normal GPC	34	38	35
Graphene GPC	41	43	42.2

The compressive strength result's for 10M(Molarity) geopolymer concrete(GPC) and graphene geopolymer concrete(GGPC)

Compressive strength in N/mm^2 for 28 days			
Specimens	S1	S2	S3
Normal GPC	37	41.6	39
Graphene GPC	42	48	45

The compressive strength result's for 12M(Molarity) geopolymer concrete(GPC) and graphene geopolymer concrete(GGPC)

Compressive strength in N/mm² for 28 days			
Specimens	S1	S2	S3
Normal GPC	40.2	43	41.7
Graphene GPC	47	52.3	48

Comparing and plotting Graphs

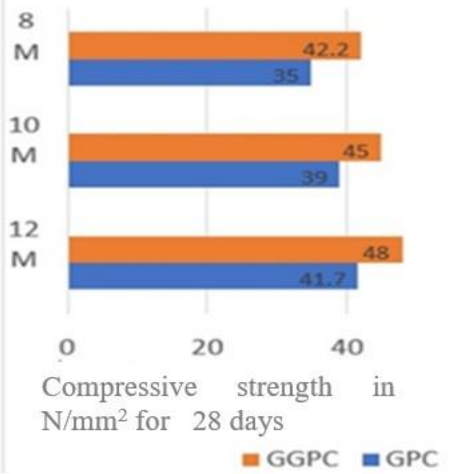

Fig 2 showing compressive strength comparison of normal geopolymer concrete with graphene geopolymer concrete.

For 28 days the graph is plotted between compressive strength of geopolymer concrete and graphene geopolymer concrete to that of different molarities

B. Durability Testing:

The durability of normal geopolymer and grapheme geopolymer concrete is calculated and compared to study the graphene influence over normal geopolymer concrete.

The durability is calculated by immersing cubes of 8M,10M,12M of normal and graphene geopolymer concrete in a tub of 2% chemicals (H2SO4, MGSO4 an NACL) and rest with distilled water and cured for 28 days.

Fig 3 showing concrete cubes dipped in curing tank filled with water and chemical.

(i)ACID (H2SO4) Attack:

The geopolymer concrete and graphene geopolymer concrete cubes of 8M, 10M and 12M are dipped in a curing tank containing 2% sulphuric acid and rest filled with distilled water. After 28 days the cubes are removed from curing tank and left for dried and later on tested for compressive strength.

Average compressive strength in N/mm² for 28 days			
	Molarity		
	8M	10M	12M
NGPC	33.12	35.7	38.06
GGPC	40.53	41.7	46.86

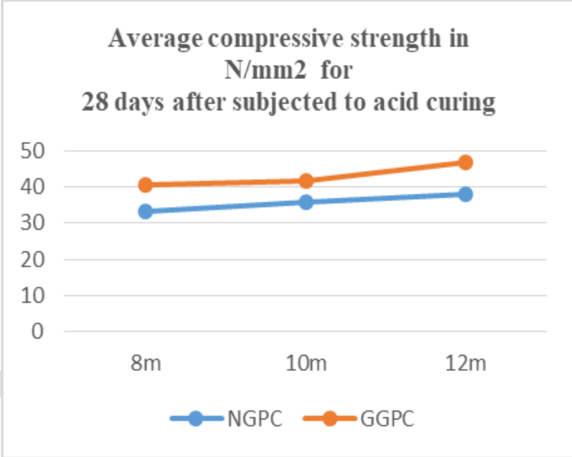

Fig 4 showing compressive strength comparison of normal geopolymer concrete with graphene geopolymer concrete after undergoing curing in acidic water.

(ii) Sulphate ($MGSO_4$) attack :

The geopolymer concrete and graphene geopolymer concrete cubes of 8M, 10M and 12M are dipped in a curing tank containing 2% Magnesium sulphate and rest filled with distilled water.

Average compressive strength in N/mm² for 28 days			
	Molarity		
	8M	10M	12M
NGPC	36.53	40.61	38.06
GGPC	43.04	46.85	51.1

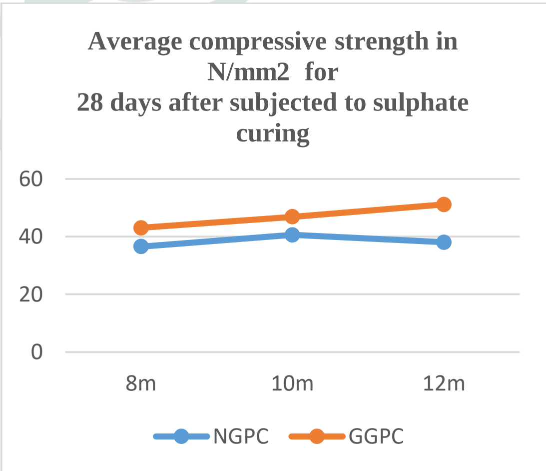

Fig 5 showing compressive strength comparison of normal geopolymer concrete with graphene geopolymer concrete after undergoing curing in sulphate water.

(iii) Chloride (NACL) attack :

The geopolymer concrete and graphene geopolymer concrete cubes of 8M, 10M and 12M are dipped in a curing tank containing 2% sodium chloride solution and rest filled with distilled water. After 28 days the cubes are removed from curing tank and left for dried and later on tested for compressive strength.

Average compressive strength in N/mm^2 for 28 days			
	Molarity		
	8M	10M	12M
NGPC	36.95	42.4	45.82
GGPC	43.74	50.3	53.1

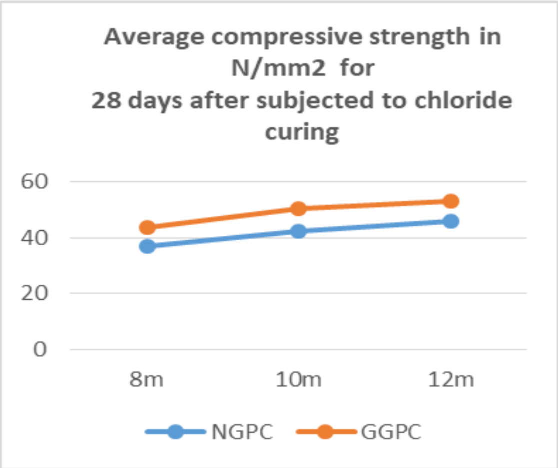

Fig 6 showing compressive strength comparison of normal geopolymer concrete with graphene geopolymer concrete after undergoing curing in chloride water.

VI CONCLUSIONS

- There is considerably increase in compressive addition of geopolymer concrete by addition of graphene,
- Maximum compressive strength of normal geopolymer concrete is observed at 12 molarity as NAOH pellets concentration is more than other mixes. Can be seen from graph.
- Maximum compressive strength of normal geopolymer concrete is observed at 12 molarity as NAOH pellets concentration is more than other mixes.
- Graphene addition to geopolymer concrete significantly improves its chemical resistance to acids can be seen from table 4.This is due to grapene is nano material and fills pores in concrete.
- There is increase in compressive strength of geopolymer concrete after undergoing into sulphate and chloride curing for 28 days tan tat of cubes cured in normal water.
- Geopolymer concrete is a green concept by avoiding use of cement which production causes 9% CO_2 emissions .Graphene addition to geopolymer concrete increases the mechanical properties as well as durability properties.

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