International Journal of Technical Innovation in Modern Engineering & Science (IJTIMES)
Impact Factor: 5.22 (SJIF-2017), e-ISSN: 2455-2585
Volume 5, Issue 06, June-2019

DURABILITY STUDIES OF GRAPHENE OXIDE AND BOTTOM ASH BASED CEMENT MORTAR

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Abstract*— The main purpose of this paper is to study the durability of cement mortar by using the graphene oxide (GO) and the bottom ash (BA) to replace natural fine aggregate in the cement mortar products. The scope of the present study is to investigate the effect of mineral admixture graphene oxide (GO) and by-products bottom ash (BA) towards the performance of cement mortar. The study shows that, based on the 1:3 and 1:5 cement/fine aggregate weight ratio while the graphene oxide is to be varied in proportion 0.1% & 0.15% and the bottom ash is to be varied in proportion 0%, 20%, 40% & 60% by its weight of natural fine aggregates in the cement mortar. In this study use high water cement ratio to conduct the experiment, in which the water cement ratio for 1:3 and 1:5 is 0.625 and 0.85. The durability studies such as water absorption, acid resistance, salt resistance and sorpitivity were conducted. From the experimental investigation, it was observed that mineral admixture of graphene oxide and industrial by-products of bottom ash plays a vital role in improving the durability parameter itself.

Keywords*—graphene oxide, bottom ash, water absorption, acid resistance, salt resistance, sorpitivity.

I. INTRODUCTION

Concrete is widely used as construction material for various types of structures due to its durability. For a long time it is considered to be very durable material requiring a little or no maintenance. Many environmental phenomena are known significantly the durability of reinforced concrete structures. We build concrete structure in highly polluted urban and industrial areas, aggressive marine environmental much other hostile condition's where other materials of construction are found to be non-durable. In the recent revision of IS: 456 – 2000, one of the major points discussed is the durability aspects of concrete. So the use of concrete is unavoidable. All the same time scarcities of aggregates are also greatly increased nowadays. Waste management is one of the most common and challenging problems in the world. The main aim of environment production agencies and government are to minimize the disposal problems and health hazards of industrial by products. Environmental pollution is an important issue with respect to sustainable development.
Concrete has the distinction of being the largest man made material in the world. Generally aggregates are cheaper than cement and impart greater volume stability and durability to mortar. The most important function of the fine aggregate is to assist in producing workability and uniformity in mixture.The investigations demonstrated that the incorporation of bottom ash can effectively change the behavior of cement mortar and durable concrete can be produced by improving the behavior of cement mortar. Worldwide over 10 billion tons of concrete are being produced every year and concrete will continue to be the domination construction material in future due to various reasons namely its durability, adaptability strength, cost effectiveness and maintenance free service life. The durability of cement mortar and concrete is defined as its ability to resist weathering action, chemical attack, abrasion, or any other process of deterioration. Durable concrete will retain its original form, quality and serviceability when exposed to its environment.

At present bottom ash is disposed of in the form of aqueous slurry in the adjoining areas, which makes large tracts of useful land barren and also poses a threat to the ecology and environment of the region. Hence, there is urgent necessity to obtain safe and economic solution for the proper uses of bottom ash, not only in India but over the entire world. .In this research, lignite corporation thermal power plant bottom ash was used as fine aggregate (natural sand replacement) in mortar. Mortar specimens were then tested for workability studies, compressive strength, porosity, acid resistance, sulphate resistance and water absorption.

II. BOTTOM ASH

Bottom ash is part of the non-combustible residue in a furnace. In an industrial, it usually refers to lignite combustible and comprises of combustibles embedded in forming clinkers and sticking to hot side walls of a lignite burning furnace during its operation. Bottom ash are produced from the power plants has to either dry or wet to an open area available near the plant and bottom ash mixing it with water and pumping into artificial damping yards.

Fig.1 Bottom ash

III. GRAPHENE OXIDE

Graphene oxide (GO) is a unique material that can be viewed as a single molecular layer of graphite with various oxygen containing functionalities such as carboxyl and hydroxyl groups. Few studies have been conducted to Elucidate the fundamental influence of GO in the cement hydration process. However, other recent research contradicts the homogeneous distribution of GO, claiming that GO regulates the formation of flower-like hydration crystals that substantially improve the mechanical strength of the composite. The flower-like crystals continue to grow and become denser over time. GO has also been reported to accelerate the degree of hydration of Portland cement (PC) paste systems this acceleration of hydration was confirmed on the basis of the increase in the non-evaporable water content and the calcium hydroxide content upon the addition of GO to the composite.

Fig.2 Graphene oxide

IV. EXPERIMENTAL INVESTIGATION

In this chapter describes the testing of materials and the experimental investigation. All tests were performed to evaluate the behaviour of the cement mortar at the fresh and hardened state. The details about the size and number of specimen to be tested were presented laboratory. The first step consists of defining the materials used in the experimental investigation.

a) TESTING ON MATERIALS

a) Test on Cement

There are several types of cement each having specific strength and specific property. Most commonly used cement was Portland Pozzolana Cement and Ordinary Portland Cement. There are three grades in Ordinary Portland cement such as OPC 33, OPC 43 and OPC 53. In this study, the Ordinary Portland Cement of grade 43 was used. Testing on this cement is very essential because the property of OPC 43 should satisfy the code IS 8112: 1989 to use it with the fine aggregate. The following test was done on the cement.

Table 1 Physical Properties of Cement (OPC 43 grade)

PROPERTY	VALUE
Specific gravity	3.15
Standard Consistency	28%
Initial setting time	130 min
Final setting time	240 min

b) Test on Fine Aggregate

Aggregate occupies most of the volume of the mortar. It is the stuff that the cement paste coats and binds together. The composition, shape, and size of the aggregate all have significant impact on the workability, durability, strength, weight, and shrinkage of the concrete. The following are test conducted on fine aggregate.

Table 2 Physical property of fine aggregate

PARAMETERS	RESULT
Specific gravity	2.6
Water absorption	1.00
Surface texture	rough
Particle shape	rounded
Gradation (as per) IS:33-1970	Zone II

c) Test on Bottom Ash

For the present study about 50 kg of bottom ash was collected from Neyveli Lignite Corporation, Thermal Power Station – 1 (Expansion). Various tests like physical properties of the bottom ash were carried out in the laboratory as detailed below.

Table 3 Physical Properties of Bottom Ash

PARAMETERS	RESULT
Specific gravity	2.57
Water absorption	4.00
Surface texture	Rough
Particle shape	Rounded

d) Test on Graphene Oxide

The micro structural material characteristics of graphene oxide can modify the physical properties of cementitious materials is given in table 4.

Table 4 Physical Properties of Graphene Oxide

PARAMETERS	RESULT
Specific gravity	1
Particle Shape	Rounded
Surface texture	Fine

b) PREPARATION OF MORTAR AND TESTING OF SPECIMENS

In order to compare the suitability of bottom ash and graphene oxide to be used in cement mortar applications, 1:3 and 1:5 mix proportions were considered. In the above nominal reference mortar proportions, bottom ash was used to replace partially sand, the replacement levels from 0, 20, 40 and 60% and addition of graphene oxide 0.1 and 0.15%, test programme for the various mortar mixes. To study the durability aspects of bottom ash and graphene oxide mortar standard moulds of 50 sqcm area (70.5x70.5x70.5 mm) were used for preparing the mortar cubes. For each type of mix, 9 mortar cubes were cast, 3 specimens were considered for each age (i.e., at 14 days, 28 days and 60 days). Cement, water,

sand, bottom ash and graphene oxide required for preparing mortar mixes were taken by weight according to the proportion 1:3 and 1:5 are thoroughly mixed.

Table 5 Test Programme for Durability studies on Cement Mortar

Mortar mix	Size of Specimen (mm)	Total no. of Specimen
M1 – 1:3 M2 – 1:5	70.5X 70.5 X 70.5	224 224

c) WORKABILITY OF MORTAR

a) Fresh property test- flow table test

The flow table test of cement mortar is done only to calculate the amount of water required for gauging for conducting strength test of masonry cement and for drying shrinkage test of cement. It also gives us some idea on the workability of cement mortar.

Fig. 3 Mortar flow table apparatus

Fig.4 Placing of bottom ash cement mortar in flow table mould

Fig.5 Shape of mortar mix after flow test

Table 6 Fresh property test-flow table test (1:3 mix ratio) code-as per IS 2250-1981

MORTAR MIX	REPLACEMENT BY BOTTOM ASH (%)	CEMENT (GM)	SAND (GM)	BOTTOM ASH (GM)	QTY. OF WATER (ML)	FLOW VALUE (%)	W/C RATIO
1:3	0	200	600	-	125	116	0.625
1:3	20	200	480	120	125	113	0.625
1:3	40	200	360	240	125	110	0.625
1:3	60	200	240	360	125	102	0.625

Table 7 Fresh property test-flow table test (1:5 mix ratio) code-as per IS 2250-1981

MORTAR MIX	REPLACEMENT BY BOTTOM ASH (%)	CEMENT (GM)	SAND (GM)	BOTTOM ASH (GM)	QTY. OF WATER (ML)	FLOW VALUE (%)	W/C RATIO
1:5	0	133.33	666	-	130	126	0.85
1:5	20	133.33	532	133.2	130	123	0.85
1:5	40	133.33	400	266.4	130	117	0.85
1:5	60	133.33	266	399.6	130	108	0.85

V. DURABILITY PROPERTIES OF TEST ON CEMENT MORTAR

a. GENERAL

Durability of cement mortar is essential because it should be capable of withstanding the conditions for which it has been designed throughout the life span of the structure. The term durability is used to characterize in broad sense the resistance of mortar to a variety of physical or chemical attacks due to either external or internal causes. In this study, an attempt was made to evaluate the effect of bottom ash (BA) and graphene oxide (GO) on cement mortar. Water absorption, sorpitivity, acid resistance and salt resistance of bottom ash (BA) and graphene oxide (GO) on cement mortar were studied to understand the durability characteristics. For the series of percentage of replacement of sand by bottom ash mortar mixes varying from 0, 20, 40 and 60% and addition of graphene oxide mortar mixes varying from 0.1 and 0.15%, an attempt was made to evaluate the durability characteristics of mortar mixes using 70.5 mm cube specimens.

b. WATER ABSORPTION

The water absorption test was performed on 70.5mm cubes according to ASTM C 642 by drying the specimens in an oven at a temperature of 105^{o}C to a constant mass then immersing it in water after cooling to room temperature. A total of 144 cube specimens were used for these tests at the age 14, 28 and 60 days. The specimens were taken out of the water at regular intervals of time and weighed. The process is continued till the weights become constant. The difference between the water saturated mass and oven dry mass expressed as a percentage of an oven dry mass gives the saturated water absorption. Water absorption is a measure of the porosity in cement mortar, which is occupied by water in saturated condition. It denotes the quantity of water which can be removed on drying a saturated specimen. Water absorption was determined by the following equation. Water absorption = ((wet weight – dry weight)/ dry weight) x 100 in %.

Fig.6 Curing of Mortar Specimen for Water Absorption

Fig. 7 Oven at 105^{o}C Temperature on Specimens

Fig. 8 Wet Weight

Fig. 9 Dry Weight

c. **SORPTIVITY**

Sorptivity measures the rate of penetration of water into the pores of cement mortar by capillary section. When the cumulative volume of water penetrated per unit surface area of exposure, is plotted against the square root of time of exposure, the resulting graph could be approximated by a straight line passing through the origin. The slope of this straight line is considered as a measure of the rate of movement of water through the capillary pores and is called the sorptivity. This test evaluates the quality of mortar based on surface pores of the mortar specimens. Immediately after the immersion into water the starting time of the test was recorded. At intervals of 15, 30, 45 and 60 minutes after the start of the test, the specimens were removed from the tub and after the surplus water was wiped off with tissue papers. The specimens were weighed to the nearest 0.01 gm and then returned to the tub. The relationship between water sorption and time was determined by the relationship given in the following equation:

$$I = S \sqrt{t}$$

Where, S (in mm/√min) is the water sorptivity of the mortar and i (mm) is the cumulative absorbed volume per unit area of inflow for duration of time ´t'.

Fig. 10 Sorptivity Test on Specimen

d. **ACID RESISTANCE**

The chemical resistance of the cement mortar was studied through chemical resistance by immersing mortar cubes in an acid solution. For this test, the acid solution was prepared by adding 5% H_2SO_4 in distilled water. The initial weight of all the specimens were found and identified with number before the immersion. Then the weighed specimens were immersed in the acid solution for 14, 28 and 60 days. Care is taken to maintain a minimum of 40mm distance between the cubes placed in tubs containing acid solutions. The pH value of the acidic media was at 0.3. The pH value was periodically checked and maintained at 0.3. After the specified period the specimens were taken out from the acid and it was allowed to dry for 24 hours at room temperature. Then the specimens were brushed with a soft nylon brush and rinsed in tap water to remove loose surface material. Then the final weights of the cubes were found and loss of weight in percentage was calculated.

Fig. 11 Mortar Cubes Specimens Immersed in H_2SO_4

Fig. 12 Acid Attack Mortar Cubes Specimens in 14, 28 and 60 days

e. SALT RESISTANCE

The salt resistance tests were performed the resistance of mortar cubes subjected to salt water attack. The cement mortar cubes were studied through chemical resistance by immersing mortar cubes in salt water with 3% diluted sodium chloride. The initial weight of all the specimens were found and identified with number before the immersion. Then the weighed specimens were immersed in the chloride solution for 14, 28 and 60 days. Then the specimens were taken out from salt water and the surfaces of the cubes were cleaned. Then the final weights of the cubes were found and loss of weight in percentage was calculated.

Fig. 13 Mortar Cubes Specimens Immersed in Sodium Chloride

Fig. 14 Salt Attack Mortar Cube Specimens in 14, 28 and 60 days

VI. RESULTS AND DISCUSSION

a. GENERAL

In this chapter, the results of the studies on the durability characteristics of mortar (partial replacement of sand by bottom ash and addition graphene oxide) are presented and are discussed. It is very important to consider the durability of mortar as it has indirect effect on economy, serviceability and maintenance. A concrete structure is said to be durable if it withstands the conditions for which it has been designed, without deterioration, over the past year, the term durability characterizes the resistance of mortar to a variety of physical and chemical attacks due to either internal and external causes. In this section the various parameters that influence the durability of mortar mixes are discussed. For the series percentage of replacement of fine aggregate by bottom ash varying from 0, 20,40 and 60% and addition of graphene oxide varying from 0.1 and 0.15% as seen that the results of durability of mortar values increases and the corresponding increase the bottom ash content.

b. WATER ABSORPTION

The test results of water absorption of cement mortar at different replacement levels of bottom ash and addition graphene oxide. Water absorption for cement mortar investigated after 14, 28 and 60 days are found to be in the range of mix

proportion 1:3 and 1:5 maximum and minimum values are respectively. Result show that for mix proportion, water absorption increases as the percentage replacement of bottom ash and addition of graphene oxide in percentage content increases.

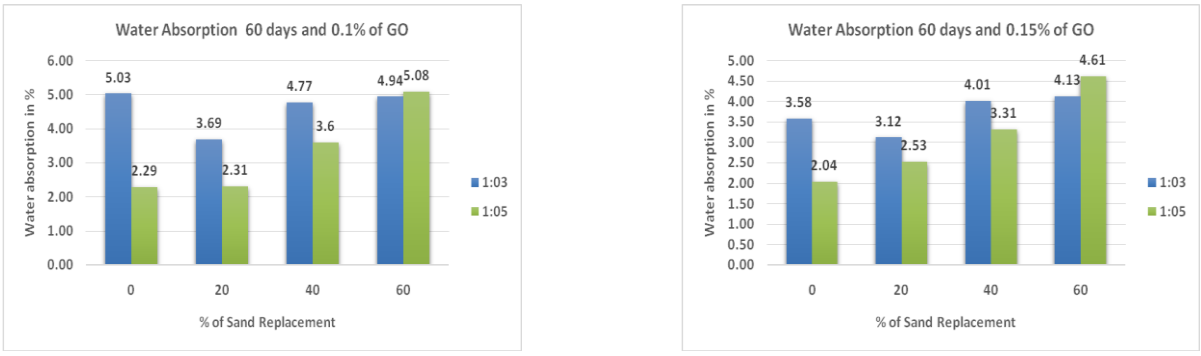

Fig. 15 Comparing Water Absorption 60 days for Mix 1:3 and 1:5 Using 0.1% and 0.15% of GO

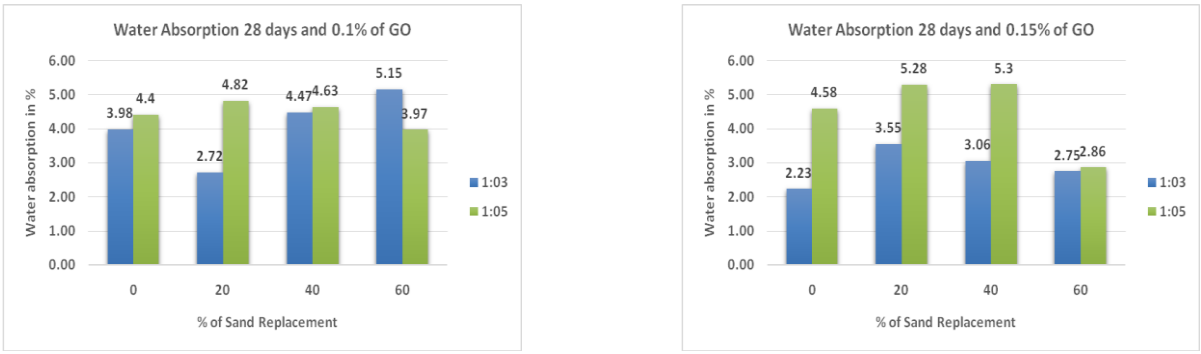

Fig. 16 Comparing Water Absorption 28 days for Mix 1:3 and 1:5 Using 0.1% and 0.15% of GO

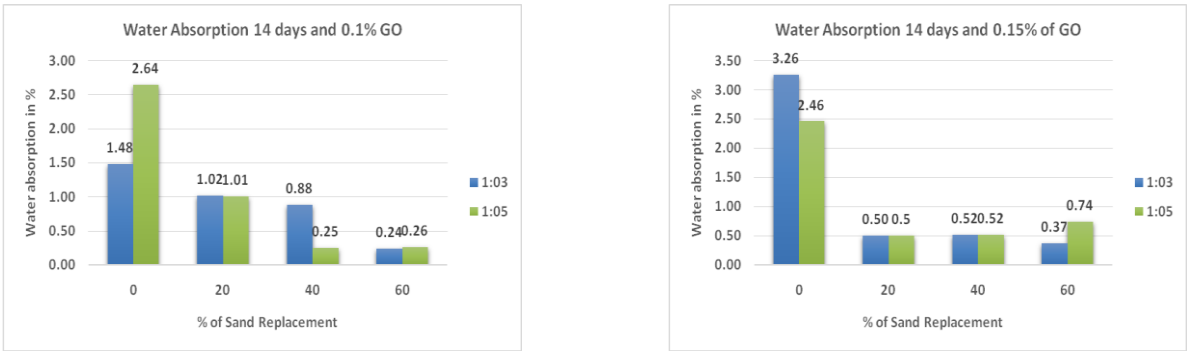

Fig. 17 Comparing Water Absorption 14 days for Mix 1:3 and 1:5 Using 0.1% and 0.15% of GO

c. **SORPTIVITY**

Results of water sorption (mm/√min) for various replacement level of bottom ash and addition of graphene oxide mortar mixes.

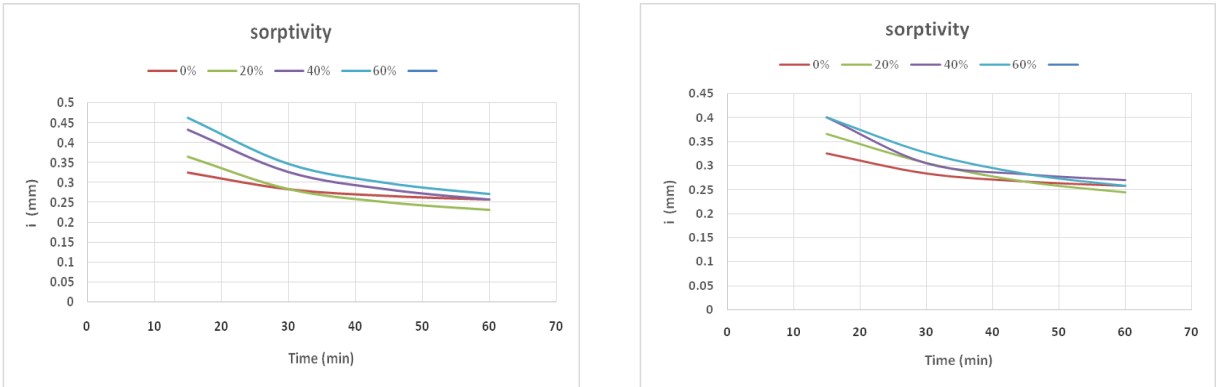

Fig. 18 Sorptivity of Mix 1:3 Using BA and 0.1%, 0.15% of GO

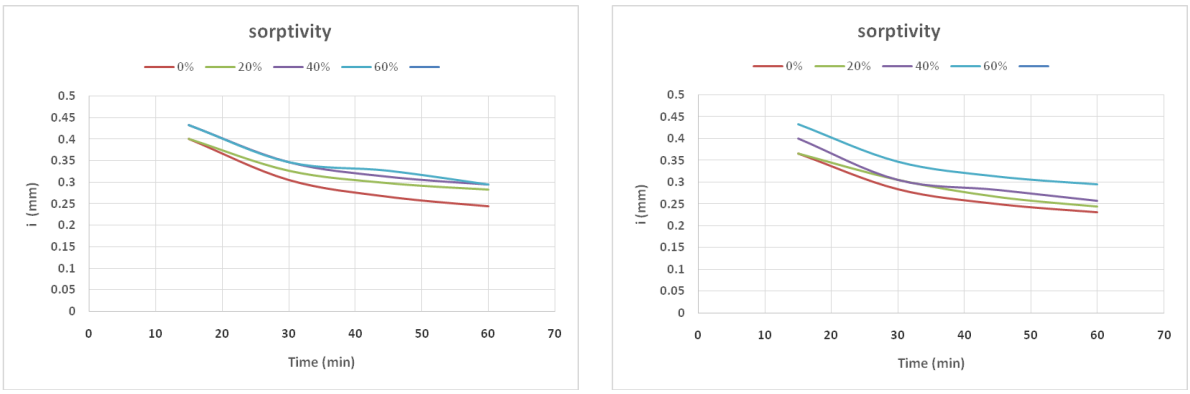

Fig.19 Sorptivity of Mix 1:5 Using BA and 0.1%, 0.15% of GO

d. **ACID RESISTANCE**

The test results of Acid resistance of cement mortar at different replacement levels of bottom ash and addition graphene oxide. Acid resistance for cement mortar investigated after 14, 28 and 60 days are found to be in the range of mix proportion 1:3 and 1:5 maximum and minimum values are respectively. Result show that for mix proportion, Acid resistance increases as the percentage replacement of bottom ash and addition of graphene oxide in percentage content increases.

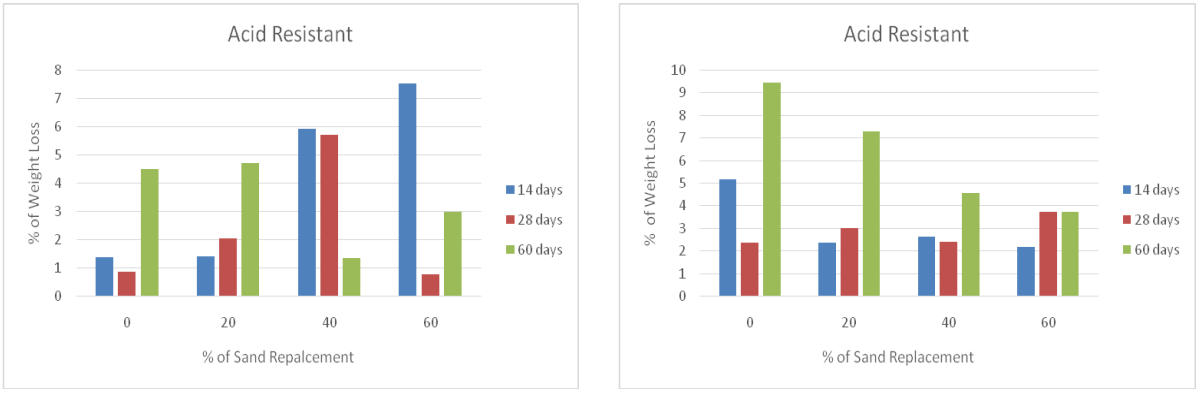

Fig. 20 Acid Resistant of Mix 1:3 Using BA and 0.1%, 0.15% of GO

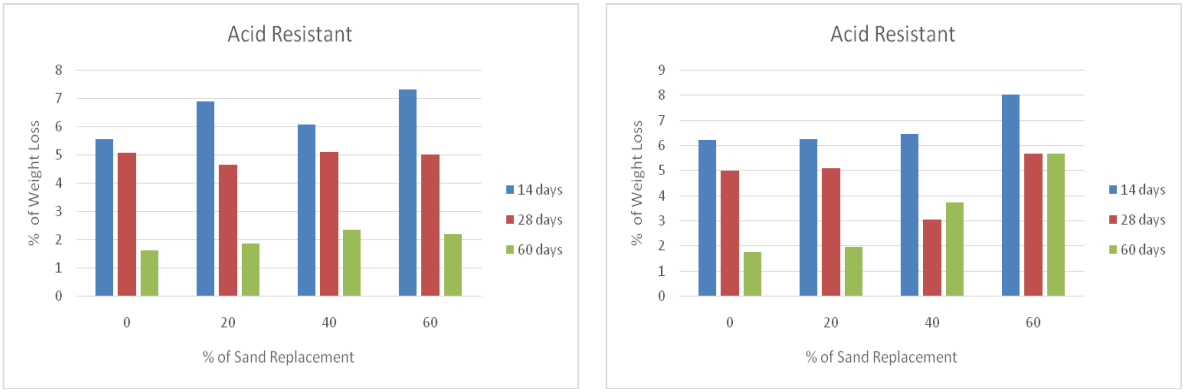

Fig. 21 Acid Resistant of Mix 1:5 Using BA and 0.1%, 0.15% of GO

e. **SALT RESISTANCE**

The test results of Salt resistance of cement mortar at different replacement levels of bottom ash and addition graphene oxide. Salt resistance for cement mortar investigated after 14, 28 and 60 days are found to be in the range of mix proportion 1:3 and 1:5 maximum and minimum values are respectively. Result show that for mix proportion, Salt resistance increases as the percentage replacement of bottom ash and addition of graphene oxide in percentage content increases.

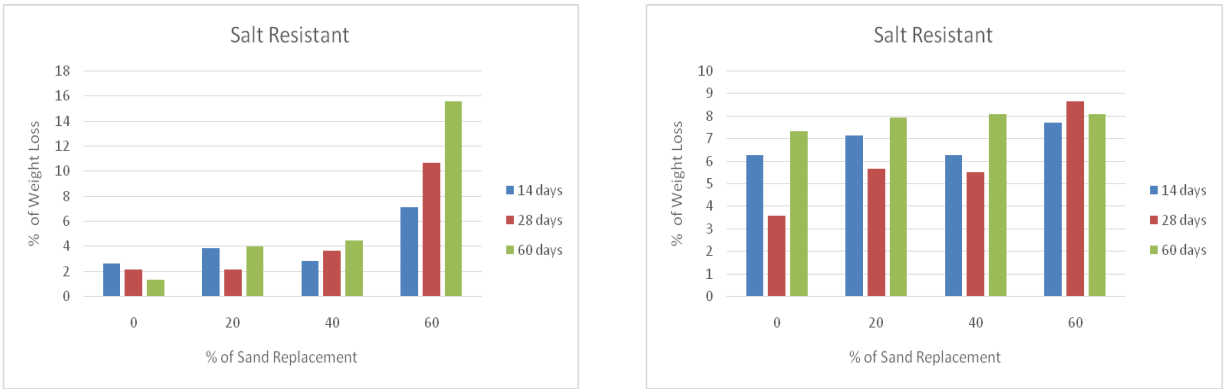

Fig. 22 Salt Resistant of Mix 1:3 Using BA and 0.15% of GO

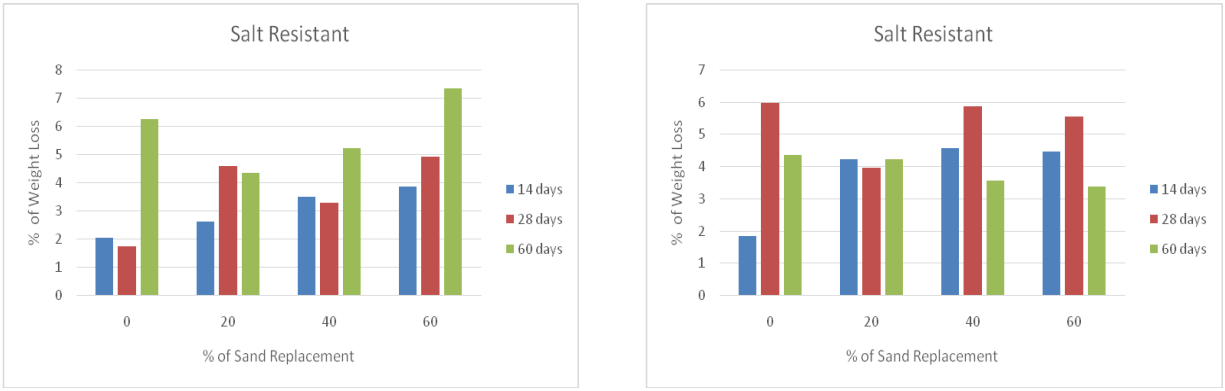

Fig. 23 Salt Resistant of Mix 1:5 Using BA and 0.15% of GO

VII. CONCLUSION

Based on the experimental studies carried out on the effect of bottom ash and graphene oxide on cement mortar, the following conclusions are drawn.

1. According to the test results, it can be conclude that cement mortar of material combination can be produced successfully.
2. The durability characteristics of cement mortar are increased by using admixture of graphene oxide and industrial by-product of bottom ash.
3. The cement mortar mixes using 1:3 and 1:5 with partial replacement of sand by bottom ash in percentage of 0, 20, 40, and 60% and addition of graphene oxide in percentage of 0.1 and 0.15% were studies at the age 14, 28 and 60 days.
4. This durability studies such as water absorption, sorpitivity, acid resistance and salt resistance.
5. The weight loss was found in acid immersion. Addition of 0.1% and 0.15% of graphene oxide and 20% and 40% of replacement of sand by bottom ash shows good resistant to acid attack when compared with reference mortar mixes.
6. The weight loss was found in salt water immersion. Addition of 0.1% and 0.15% of graphene oxide and 20% and 40% of replacement of sand by bottom ash shows good resistant to salt attack when compared with reference mortar mixes.
7. Water absorption of 20% of bottom ash mortar cubes are 2.5% less than that of reference mortar mixes therefore 20% of bottom ash cement mortar is more durable when compared to other mixes.
8. Sorptivity of bottom ash and graphene oxide mortar mixes is found to be of the order of $mm/min^{0.5}$ which shows that the quality of mortar mixes are comparable to the reported values of graphene oxide and bottom ash based cement mortar.
9. This may due to the fact that the bottom ash and graphene oxide which also acted as a filler material and increasing the density of the cement mortar by filling the voids and the results of mass loss reduction.
10. Result show that for all mix proportion, water absorption, sorpitivity, acid resistance and salt resistance increases as the percentage replacement of bottom ash and addition of graphene oxide content increases.
11. All specimens including reference mix showed significant durability properties, nevertheless the improvement of cement mortar properties was more considerable in the case of adding graphene oxide and industrial by product of bottom ash partially replacement of sand.

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