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Experimental Investigations to Determine the Chloride attack on Medium and High Strength Concrete under the Influence of GGBS

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***Abstract*— *Concrete is a widely-used material in construction industry, because it has naturally and easily available ingredients like cement aggregate and water. Production of cement creates environmental problem like emission of CO_2 in the production process of cement. So, there is serious need to find ways and means to reduce CO_2 emission. To overcome this problem Ground Granulated Blast Furnace Slag, which is a pozzolanic material can be used as a partial replacement to cement.*

The main components of GGBS are CaO (30-50%), SiO_2 (28-38%), Al_2O_3 (8-24%), and MgO (1- 18%). In general, increase in CaO content of the slag increases slag basicity and therefore improves the compressive strength. As it is available from the literature, strength and durability are the two important mechanical properties to make reliable concrete. Many investigations are available on the strength properties of GGBS concrete with different replacement levels of GGBS. However, durability studies on medium and high strength concrete over different replacement levels of GGBS. In the present study, GGBS was replaced with cement to obtain the influence of GGBS in normal and high strength concrete on durability properties. Comparisons were made with different percentage of replacements of GGBS for cement, which helped to arrive at the optimum percentage of replacement. Cement was replaced by GGBS at 0, 20, 30, 40 and 50% by weight of cement in conventional concrete and high strength concrete. Over 200 cubes and cylinders were casted, cured and tested for 28 and 56 days. Various durability tests were conducted on specimens such as, sulphate resistance, acid attack, and compression strength and water absorption test.

Keywords*— Chloride attack, GGBS replacement, Residual strength.

I. INTRODUCTION

Concrete is a widely-used material in construction industry, because it has naturally and easily available ingredients like cement aggregate and water. It has numerous applications because of its strength, ease of moulding and also cheap availability of its ingredients. Cement is one of the most important ingredients of concrete because of its binding properties. Increase in production of cement creates environmental problem like emission of CO_2 in the production process of cement [6]. One tonne of CO_2 is released to atmosphere when one tonne of OPC is manufactured which has very harmful effect on the environment. The emission of CO_2 depends upon the type of production processes, their efficiency; fuel used, yet concrete is a desirable construction material with relatively low embodied energy, very useful thermal mass and high potential durability. [7]. so, there is serious need to find replacements for cement. To overcome this problem GGBS which is a pozzolanic material can be used as a partial replacement to cement. As GGBS is a waste from the iron industry and has chemical and physical properties like cement. So, it serves 2 purposes. 1. To replace cement partially. 2. To overcome the problem of disposal of GGBS.

From structural point of view, GGBS replacement reinforced lower heat of hydration, higher endurance and higher obstructed to sulphate and chloride intrusion when contrasted with normal ordinary concrete. On the farther hand, it also enriches to environmental resistance because it curtails the use of cement during the production of concrete. The main components of blast furnace slag are CaO (30-50%), SiO2 (28-38%), Al_2O_3 (8-24%), and MgO (1- 18%). In general, booming the CaO content of the slag terminates in raised slag basicity and a rise in compressive strength. GGBS is used to make reliable concrete structures. GGBS has been broadly used in Europe and progressively in Japan and Singapore for its Excellency in concrete durability, continuing the lifetime of buildings from fifty years to a hundred years' strength. [7]

II. MATERIALS AND EXPERIMENTS

Characterization of materials is a very important stage in research work. Various materials were tested for their engineering properties and also mechanical properties.

CEMENT: In the current investigation, Zuari 43 grade OPC conforming to IS 8112-2013 has been utilized. The physical properties of the cement were found to be as per IS 8112-2013 and has been mentioned below (Table 1).

FINE AGGREGATES: Natural river sand is the most preferred choice as a fine aggregate material. It is mined from river beds and sand mining has disastrous environmental consequences. River sand is becoming scarce and its use needs to be stopped or reduced. Use of other alternatives to River sand has become necessary. Manufactured sand (M-sand) is proving to be a great alternative for river sand and has gained immense popularity in India in recent years. Specific gravity, bulk density and particle size distribution of M-sand is almost similar to River sand. The fine aggregates satisfied the specifications as per IS 383-1970.

Table.1: Requirements of cement properties as per IS 8112: 2013

Sl. No	**Properties**	**Requirements as per IS 8112 : 2013**
1	Fineness	Not more than 10%
2	Soundness	Not less than 10 mm
3	Initial Setting Time	Not less than 30 min
4	Final Setting Time	Not more than 600 min
5	3 days Compressive Strength	Not less than 23 N/mm^2
6	7 days Compressive Strength	Not less than 33 N/mm^2
7	28 days Compressive Strength	Not less than 43 N/mm^2

COARSE AGGREGATES: Coarse aggregates are important to concrete as they play an important role in the attainment of strength in concrete. The strength of the concrete depends on the size and the grading of the coarse aggregates. Small sized coarse aggregates produce higher strength of concrete as the amount of stress concentrated around the aggregate particles is much lesser which is caused due the differences between the elastic moduli of the paste and aggregate. The coarse aggregates used in the current studies were found conforming to the codal provisions in IS 383-1970.

GGBS used for the present investigation was borrowed from RMC Ready-mix India.

SUPER PLASTICIZER : Conplast SP 430 which is commercially marketed by Fosroc Chemicals India Pvt Ltd was used as the super plasticizer in M60 grade High Strength Concrete.

WATER: As per IS 456:2000 for both mixing and curing of concrete, potable water free from harmful salts was used.

MIX PROPORTION USED IN THE STUDY

Based on the results observed from the trial mixes following mix proportions for HSC and MSC was adopted for the present investigation as shown below in table 2.

Table.2: Mix proportions of HSC and MSC

MATERIALS	MSC	HSC
Water binder ratio	0.4	0.29
Cement (kg/m^3)	420	504.21
Fine Aggregate (kg/m^3)	710	663.26
Coarse Aggregate(kg/m^3)	1123	1108.13
Water (kg/m^3)	168	146.28
Super plasticizer (kg/m^3)	-	7.563

As the grade of concrete increased the cement content also increased and water content in high strength concrete was decreased. Super plasticizer was used only in the M60 grade concrete and not in the medium strength concrete.

SPECIMEN CASTING

The test was intended to study the durability parameters of HSC and MSC with varying replacement levels of GGBS. A total of 150 Cubes of 100mm x 100mm x 100mm, 240 cylinders of 100mm x 200mm were casted.

PLACING OF CONCRETE

Due to the enormity of work including setting up of moulds, pouring of concrete, compacting and finishing, the concrete casting had to be done for about 10 hours for each set. The Fig 1 shows the placing of concrete in to the moulds.

Fig.1: Placing of concrete in to the moulds.

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III. EXPERIMENTAL INVESTIGATION

Durability of the concrete deals with the sustainability of concrete when exposed to environmental conditions. Though in controlled lab conditions the concrete specimens may exhibit good strength but in actual field the conditions are different. The concrete building may be exposed to severe weathering and environmental conditions which may increase its degradation and cause a reduction in strength. Hence to observe the durability of concrete, the durability tests are acid attack resistance, sulphate attack resistance, chloride attack resistance, water absorption test, sorptivity tests were conducted in lab.

CHLORIDE RESISTANCE TEST

Chloride attack is one of the most important aspects for consideration when we deal with the durability of concrete. Chloride attack is particularly important because it primarily causes corrosion of reinforcement. Statistics have indicated that over 40 per cent of failure of structures is due to corrosion of reinforcement. Due to high alkalinity of concrete a protective oxide film is present on the surface of steel reinforcement. The protective passivity layer can be lost due to carbonation. This protective layer also can be lost due to the presence of chloride in the presence of water and oxygen. In reality, the action of chloride in inducing corrosion of reinforcement is more serious than any other reasons. One may understand that Sulphates attack the concrete whereas the chloride attacks steel reinforcements. ASTM C1202 – 17 was referred for chloride resistance tests on concrete.

TEST PROCEDURE

The cube specimens of size 150mm X 150mm X 150mm were used to conduct this test. After 28days of curing of concrete specimens were taken off from water and were kept for dry. The initial dry weights of the specimens were found. The solution of Sodium chloride (NaCl) was prepared by 5% weight of NaCl was mixed with potable water. The cubes were agitated till all the particles of NaCl crystals get completely dissolved in water. The cubes were then immersed in the solution. After each specified period, these specimens were taken off from the solution and kept for surface dry. The surfaces of the cubes were cleaned and the final dry weights and compressive strength of the specimens were found. And determined the % weight loss and % reduction in strength using eqn. (I).

Percentage weight loss = $\frac{W_1 - W_2}{W_1} X\ 100$ eqn…1

where,

w_1 =initial weight of specimen in kg

w_2 =final weight of specimen after immersion in water in kg

Weight analysis of concrete for chloride attack at different time periods for M40 grade concrete.

IV. RESULTS

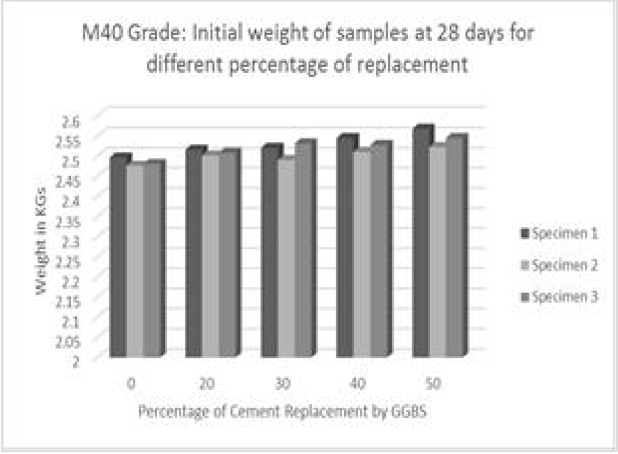

Fig.2: Initial weight of samples at 28 days for different percentage of replacement after chloride attack (M40)

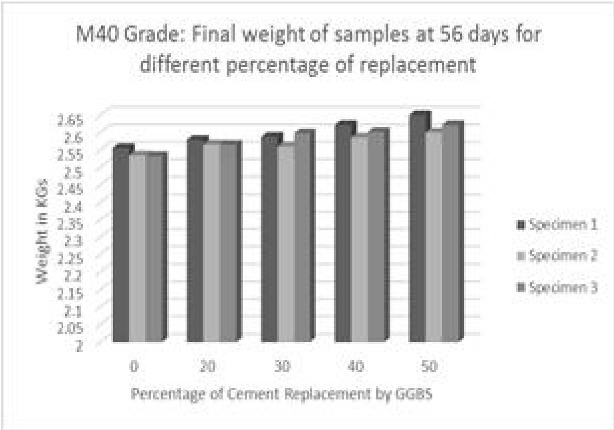

Fig.3: Final weight of samples at 56 days for different percentage of replacement before chloride attack (M40)

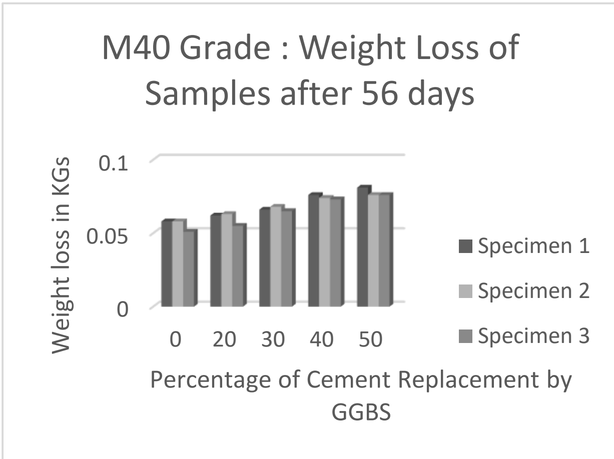

Fig.4: Weight Loss of Samples after 56 days for chloride attack (M40)

Figures 2, 3, 4 represent the initial weights, final weights and the weight loss of specimens after immersion in chloride solution.

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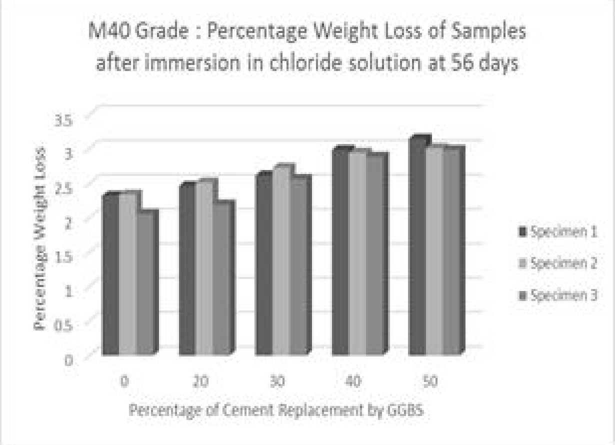

Fig.5: Percentage Weight Loss of Samples after immersion in chloride solution at 56 days (M40)

The difference of weights of specimen was recorded after 28 and 56 days of immersion in chloride solution. Figure 5. shows the weight loss in percentage for M40 grade of concrete.

Weight analysis of concrete for chloride attack at different time periods for M60 grade concrete

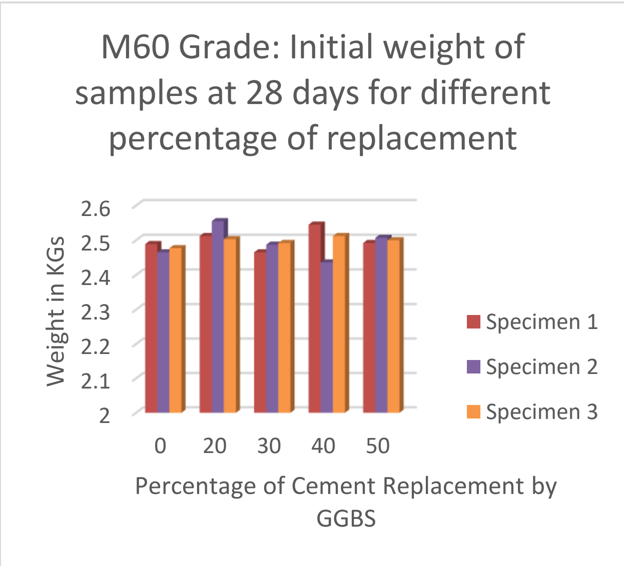

Fig.6: Final weight of samples at 56 days for different percentage of replacement after chloride attack (M60)

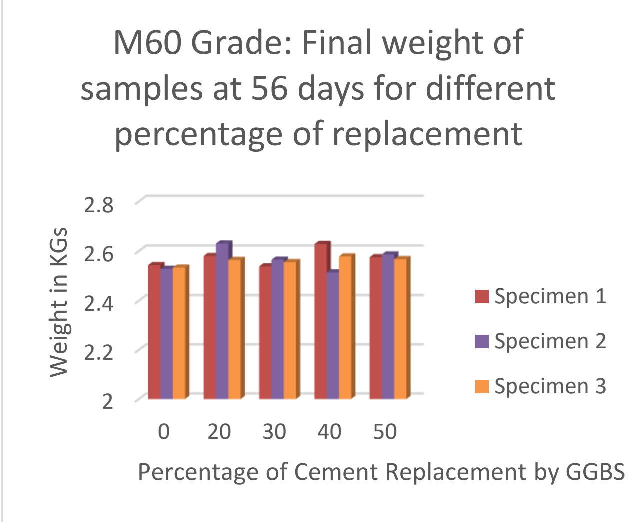

Fig.7: Initial weight of samples at 28 days for different percentage of replacement before chloride attack (M60)

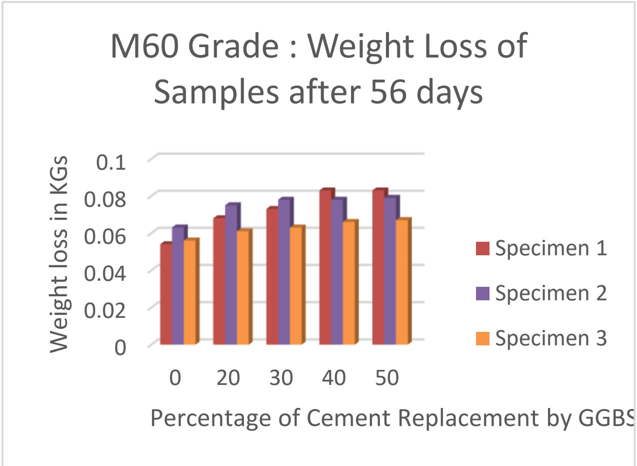

Fig. 8: Weight Loss of Samples after 56 days for chloride attack (M60)

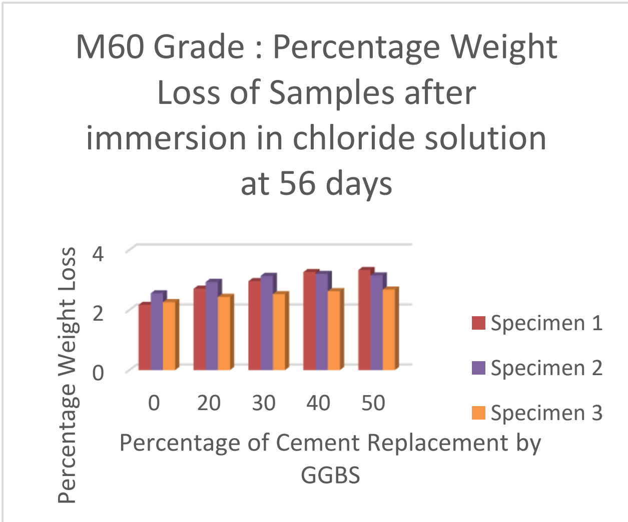

Fig.9: Percentage Weight Loss of Samples after immersion in chloride solution at 56 days (M60)

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The difference of weights of specimen was recorded after 28 and 56 days of immersion in chloride solution. Figure 9. shows the weight loss in percentage for M60 grade of concrete.

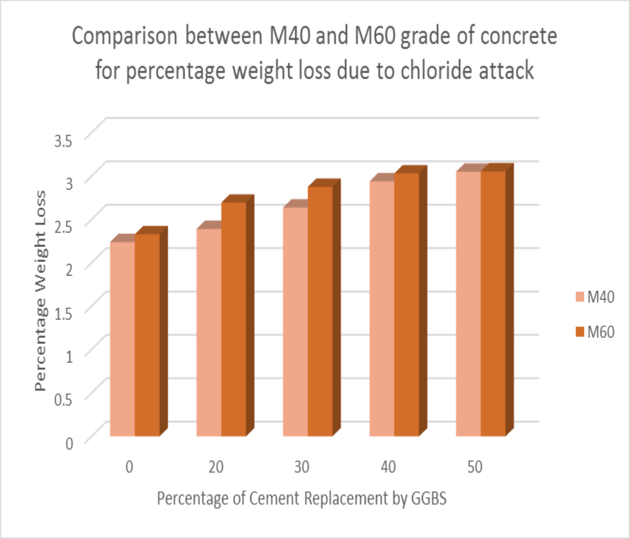

Fig.10: Comparison between M40 and M60 grade of concrete for percentage weight loss due to chloride attack

Figure 10. represents the comparison graph of M40 and M60 grade concrete for chloride attack tested after 56 days. In reference to the figure 10. conclusions were drawn.

Residual Compressive Strength after Chloride attack

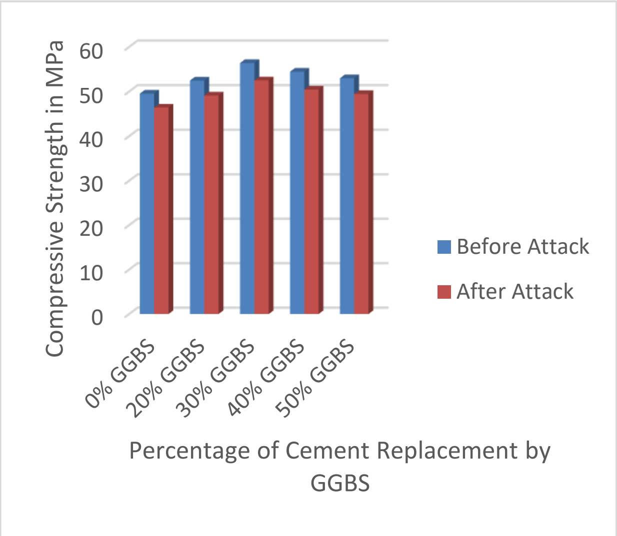

Fig.11: Residual Compressive Strength before and after Chloride attack for M40 Concrete (28 Days)

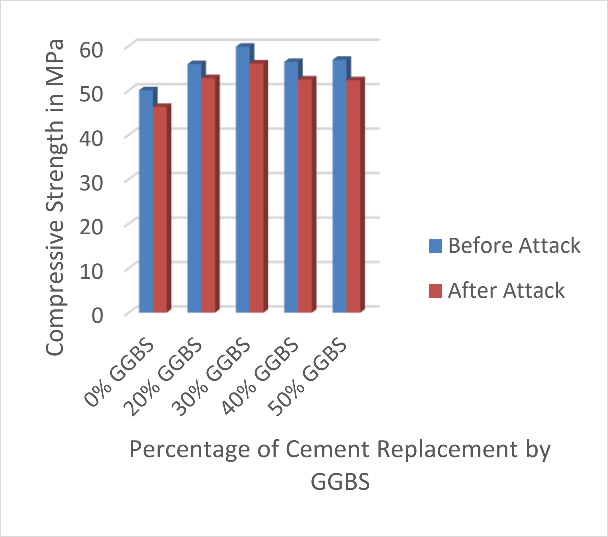

Fig12: Residual Compressive Strength before and after Chloride attack for M40 Concrete (56 Days)

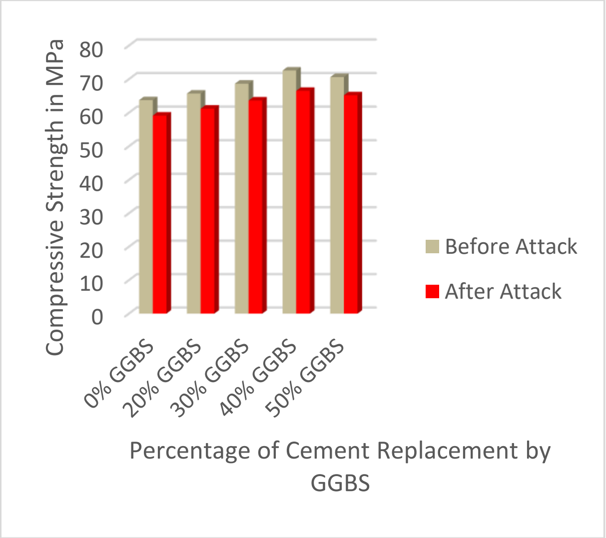

Fig.13: Residual Compressive Strength before and after Chloride attack for M40 Concrete (28 Days)

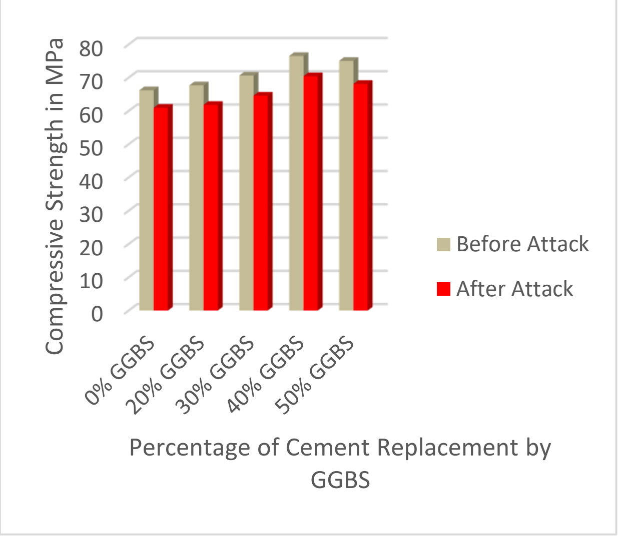

Fig.14: Residual Compressive Strength before and after Chloride attack for M40 Concrete (56 Days)

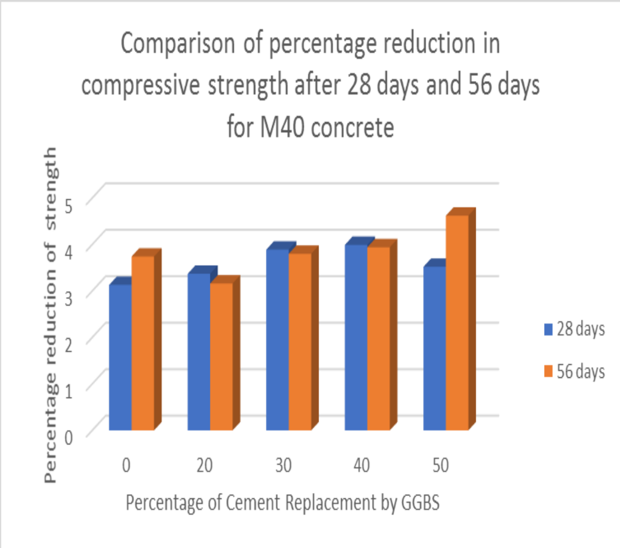

Fig.15: Comparison of percentage reduction in compressive strength after 28 and 56 days for M40 concrete

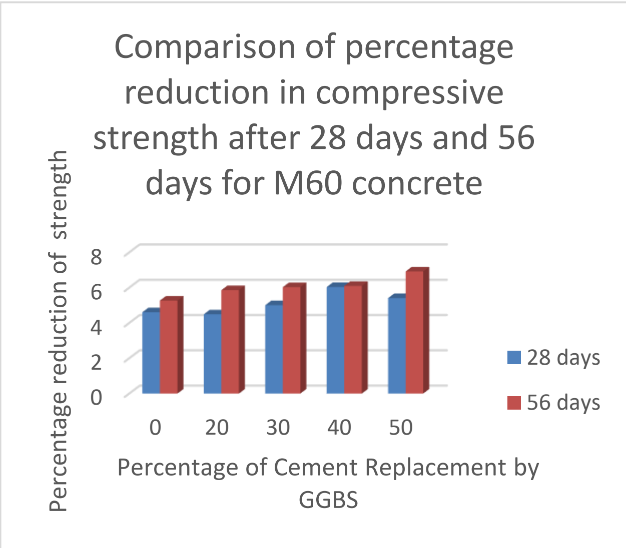

Fig.16: Comparison of percentage reduction in compressive strength after 28 and 56 days for M60 concrete

V. CONCLUSIONS

1. After analysing the data from the graphs, it can be inferred that for both M40 and M60 grade of concrete, at 50% replacement of cement by GGBS, it can be seen that there was lesser percentage of weight loss due to chloride attack as compared to 0%, 20%, 30%, and 40%.
2. As the percentage of cement replacement of GGBS increased, percentage of weight reduction in both M40 and M60 grade concrete decreased.
3. In case of chloride attack, for both M40 and M60 concrete, at 50 % replacement there was almost same amount i.e. 3% of weight loss was observed in both the specimens.

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