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Experimental Study to Reduce Carbonation Effect on Concrete

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***Abstract**:*
In this paper the authors have reviewed the carbonation studies which are a vital durability property of concrete. One of the major causes for deterioration and destruction of concrete is carbonation. The mechanism of carbonation involves the penetration carbon dioxide (CO2) into the concrete porous system to form an environment by reducing the pH around the reinforcement and initiation of the corrosion process. The paper also endeavours to focus and elucidate the gravity of importance, the process and chemistry of carbonate and how the various parameters like water/cement ratio, curing, depth of concrete cones, admixtures, grade of concrete, strength of concrete, porosity and permeability effect carbonation in concrete. The role of Supplementary Cementitious Materials (SCMs) like Ground granulated Blast Furnace Slag (GGBS) and Silica Fume (SF) has also been reviewed along with the influence of depth of carbonation.
***Keywords**:*
Carbonation, compressive strength, Water Absorption, GGBS, Silica fumes.

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I. INTRODUCTION

Carbonation is widely recognized as a significant cause of corrosion of reinforcement in concrete. Corrosion of reinforcement is found be the major cause of deterioration of concrete structures all around the world. The basic mechanism involved in this process is atmosphere reacts with hydrated cement and destroys its property of alkalinity. The transport properties like porosity, permeability, diffusion and capillarity show their effect on carbonation. They also effect the durability of concrete since they control the influence of chlorides. The paper reviews the effect of curing age on carbonation of concrete made of these SCM and it also identifies the relationship between permeability and curing age, strength with the depth of carbonation of concrete. Durability of concrete structures is very much important when the structures are openly exposed to the aggressive environments. Carbonation destructs the structure and reduces its service life. Carbonation is a process by which the atmosphere reacts with hydrated cement products to form calcium carbonate thereby alkalinity of the concrete is reduced. In fact the negative effects of carbonation can be reduced to the maximum extent by using high strength concrete and proper compaction making the concrete denser. Carbonation can also be reduced by low water/cement ratio. Low water/cement ratio and high strength concrete are possible by Self Compacting Concrete (SCC) where effect of carbonation is less comparatively. The carbonation is found to have tremendous impact on some of the engineering properties of concrete. Mostly its influence is predominant on compressive strength and hardness than any other properties. The depth of carbonation can be measured by spraying phenolphthalein indicator on scratched part of concrete the solution is a colourless indicator which turns purple when pH is higher than 13. This study explores the effects of replacement 0, 5,10,15,20 and 25% from cement mass by GGBS on the physical and mechanical properties in particular, the carbonation of concrete.

II. MATERIALS USED

1. Fine Aggregate: - Fine aggregate is first graded to decide the zone to which it belongs to. Generally, there are four categories of fine aggregate Zone-I, Zone-II, Zone-III & Zone-IV. In this work, sand of zone-II is chosen whose properties were given below. Generally, fine aggregate is passed through 4.75 mm sieve.

Properties :-

- Specific gravity **2.65**
- Water absorption **1.01**
- Fineness Modulus **2.699**

2. Coarse Aggregate Coarse aggregate is another fundamental raw material which gives strength, hardness and increases the volume of the concrete. Here, coarse aggregate of size 10mm & 20 mm and angular crushed shape is chosen.

Properties :-
Specific gravity **2.68**
Water absorption **0.8%**

3. Cement :- cement is one the major component in the manufacturing process of concrete. It has the property to stick to any other raw material added in the preparation process of concrete, especially when comes in contact with water and hence produces a good paste. Here, OPC 53 grade cement is used whose properties are shown below.
Properties :-
Specific gravity **3.15**
Normal consistency **30%**
Initial & Final setting time **30 min & 580 min**

4. Water:- Normal tap water is utilized in the present work in the preparation of concrete specimens.

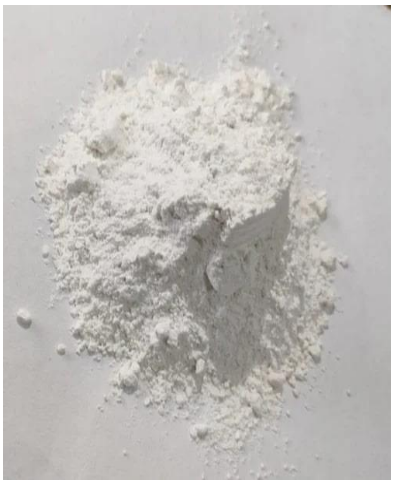
5. Silica Fumes :- Silica fume, also known as micro silica is an amorphous (non-crystalline) polymorph of silicon dioxide. It is an ultrafine powder collected as a by-product of the silicon and ferrosilicon alloy production. It is extremely fine with particles size less than 1 micron and with an average diameter of about 0.1 microns, about 100 times smaller than average cement particles. The use of silica fume as a pozzolana has increased worldwide attention over the recent years because when properly used it as certain percent, it can enhance various properties of concrete both in the fresh as well as in hardened states like cohesiveness, strength, permeability and durability. Silica fume concrete may be appropriate in places where high abrasion resistance and low permeability are of utmost importance or where very high cohesive mixes are required to avoid segregation and bleeding.

6. Ground granulated Blast Furnace Slag (GGBS) :- GGBS in this investigation commercially available. The chemical composition of GGBS, which was used in this study, is shown in Table.

Table 5. Chemical analyses of the GGBS

Oxide	Content %
SiO_2	38.2
Al_2O_3	14.5
Fe_2O_3	1.9
CaO	37
MgO	8.1
Sulphide Sulphur	0.38
MnO	3.1
Cr_2O_5	0.02
TiO_2	0.8

7. Super plasticizer:- To improve geopolymer workability, used superplasticizer based on sulfonated naphthalene formaldehyde modified was used. KUT PLAST SP400 and it is a local product.



SILICA FUMES

GGBS

III. EXPERIMENTAL WORK

Mix Design for M30 Grade of Concrete:-

Cement	Sand	Aggregate	Water	Admixture(super plasticizer)
(Kg)	(Kg)	(Kg)	(Litre)	(Litre)
50	102.5	153.5	22.5	0.255

For 1 Cub.M.

380	779	1166.6	171	1.938
1.28 Kg	2.62Kg	3.94Kg	0.6 Liter	6.54 ml

Mix Proportions:- *Replace GGBS with fine aggregate by 0%, 5%, 10%, 15% , 20%, 25%*

Partial replacement of Cement with Silica Fumes:-

The process of carbonation of concrete involves the following chemical equation which clearly depicts the reaction that takes place between atmospheric CO_2 and the products of cement hydration particularly $Ca(OH)_2$. We use 10% silica fumes in all batches of concrete mix

TESTING PROCEDURE:-

Test on Concrete:-

1. SLUMP TEST:-

Workability is a term associated with freshly prepared concrete. This can be defined as the ease with which concrete can mixed, placed, compacted and finished. Slump test is the most commonly used method of measuring 'workability' of concrete in a laboratory or at site of work. It is used conveniently as a control test and gives an indication of uniformity of concrete from batch to batch. Vertical settlement of a standard cone of freshly prepared concrete is called 'slump'.

Table 1. Slump test report for different mixes of concrete cubes

GGBS in %	Slump (mm)
0%	53
5%	55
10%	58
15%	62
20%	60
25%	58

2. COMPRESSIVE STRENGTH TEST:-

At the time of testing, each specimen must keep in compressive testing machine. The maximum load at the breakage of concrete block will be noted. From the noted values, the compressive strength may calculated by using below formula.

Compressive Strength = Load / Area

Size of the test specimen = 150mm x 150mm x 150mm

Table. Compressive strength test report for different mixes of concrete cubes **After 28 days**

GGBS in %	Compressive Strength (Mpa)
0%	29.3
5%	30.1
10%	28
15%	29.5
20%	31.3
25%	30.6

2. CARBONATION TEST USING ACCELERATED CARBONATION CHAMBER :-

Making an accelerated carbonation chamber at home can be a challenging task, as it involves handling high-pressure gas and chemicals. It is recommended to seek professional help or use pre-made carbonation chambers available in the market. However, if you have prior experience in handling chemicals and high-pressure gas, here are the general steps for making an accelerated carbonation chamber:

-Materials needed:

1. A container with a lid (e.g., a metal canister or a plastic container)
2. Carbon dioxide (CO_2) tank with regulator and tubing

3. Calcium hydroxide ($Ca(OH)_2$) or lime
4. Water

Steps:

1. Choose a container with a lid that is strong enough to withstand pressure. The container should have a sealing lid that can be tightly secured.
2. Drill a hole in the container to fit the tubing of the CO_2 tank regulator. The hole should be a snug fit to avoid gas leaks.
3. Fill the container with a mixture of calcium hydroxide and water to create a slurry. The ideal ratio is 1 part $Ca(OH)_2$ to 3 parts water by weight.
4. Place the sample of concrete inside the container.
5. Connect the CO_2 tank to the regulator and tubing, then attach the tubing to the hole in the container.
6. Set the regulator to deliver a flow rate of 10 liters per minute of CO_2 gas.
7. Seal the container lid tightly to prevent any gas leaks.
8. Leave the chamber for a set duration to allow carbonation of the concrete sample.

It is important to note that the above steps are for reference only and may not be suitable for all situations. It's always recommended to consult a qualified engineer or professional for guidance and support. Safety precautions should always be taken when handling chemicals and high-pressure gas.

The process of carbonation of concrete involves the following chemical equation which clearly depicts the reaction that takes place between atmospheric CO_2 and the products of cement hydration particularly $Ca(OH)_2$.

$Ca(OH)_2 + CO_2 \rightarrow CaCO_3 + H_20$

Hydration products (calcium silicate hydrate or CSH gel) and even the residual hydrated compounds are present in all concretes.

They are

1) Tricalcium silicate (C_3S)
2) Dicalcium silicate (C_2S)

These compounds react with CO_2 as shown in the following reactions:

$CSH + 3CO_2 \rightarrow (3CaCO_3\ 2SiO_2 + 3H_2O)$

$C_3S + 3CO_2 \rightarrow H_2OSiO_2\ H_2O + 3CaCO_3$

$C_2S + 2CO_2 \rightarrow H_2O\ SiO_2\ H_2O + 2CaCO_3.$

FACTORS AFFECT RATE ON CARBONATION

The following factors have a significant effect on the rate of carbonation.

3.1 External factors:

- Ambient relative humidity
- Concentration of carbon dioxide
- Surface protection

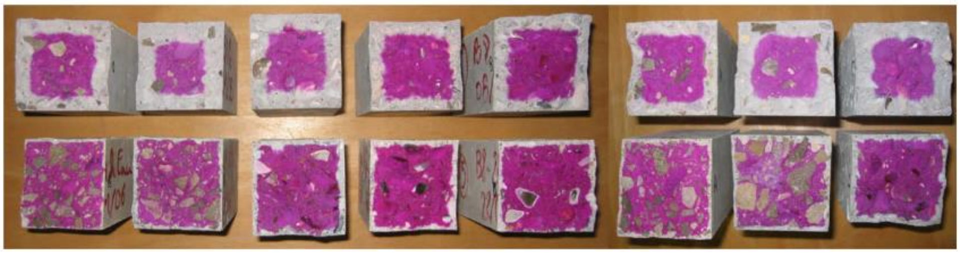
3.2 Internal factors:

- Grade of concrete
- Permeability of concrete
- Water-cement ratio

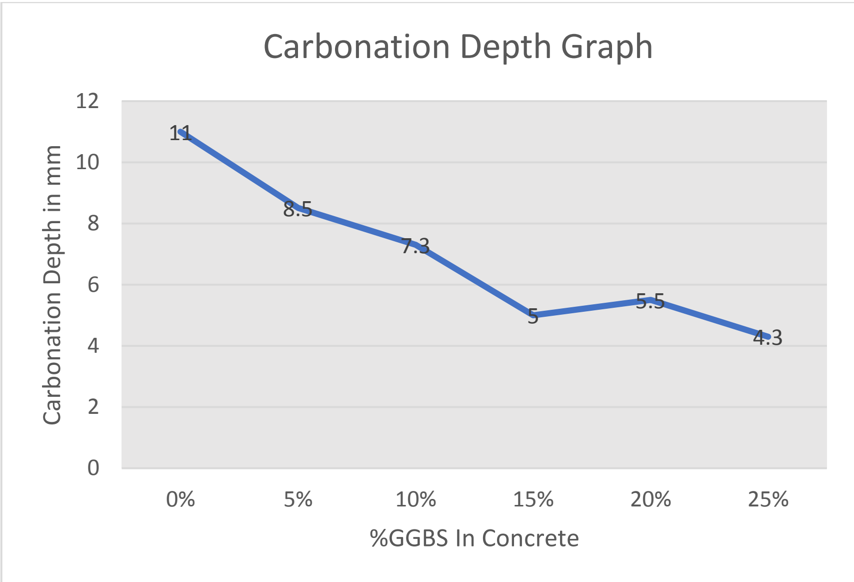
3.3 Other factors:

- Time of exposure

CARBONATION DEPTH RESULTS:



GGBS in %	Carbonation Depth (mm)
0%	11
5%	8.5
10%	7.3
15%	5
20%	5.5
25%	4.3



IV. CONCLUSION

General conclusions are drawn from the extensive review of literature on carbonation on concrete:

1. The carbonization depth increases as the period of exposure to CO2 increases, and at the same time the depth decreases by the more Fine aggregate is replaced by GGBS.

2. Additions of admixtures modifies the pore structure of the concrete and reduce the porosity and hence, decreases carbonation

3. If porosity increases carbonation depth also increases hence a linear relationship exist between accelerated carbonation and porosity.

4. Addition of SCMs like GGBS and SF reduce the porosity of concrete and reduce the depth of carbonation.

5. The application of surface coatings and provision of proper cover considerably reduces the rate of carbonation. The service life of the concrete can be enhanced.

6. The use of SCC has been proved to be the best to improve the durability characteristic of concrete in relation to the carbonation of concrete.

7. The compressive strength increases with the increase in the percentage of substitution of cement with GGBS.

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