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Behavior of Concrete under the Influence of Accelerated Carbonation

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***Abstract*: Concrete is an essential material for most sort of constructions throughout the world. It has lot of uses in our daily life. Every material has to deteriorate due to many factors in the same way the concrete also deteriorates. The carbonation process is identified as a main reason for reinforcement corrosion in concrete structure. The mechanism of carbonation includes the entrance of carbon dioxide (CO_2) into the solid permeable framework of concrete to shape a situation by decreasing the pH around the fortification and inception of the corrosion procedure. This paper investigates the impact of the carbonation on the characteristics of the concrete like strength in compression, porosity and durability. The addition of supplementary cementitious materials like fly ash is known to enhance the durability of reinforced concrete. In this paper an accelerated carbonation test has been done to assess concrete carbonation on specimens made with cement and with the partial replacement of cement by fly ash. An accelerated carbonation chamber has been constructed for creating an environment of carbonation process to occur and also the passage of carbon dioxide gas is kept constant for all the cubes. Concrete cubes are prepared for M30 grade with different percentages of FA such as 0%, 5%, 10%, 15%, 20%, 25% and 30%.**

***Keywords*: concrete, accelerated carbonation**

1. Introduction

Concrete is used in two different ways such as plain and reinforced. There is no such material that is free from degradation problem in the same way the concrete structures also undergo degradation problem. Reinforcement rusting in concrete is a considerable perishing issue that occurs because of carbonation as well as existence of chloride ions at level of reinforcement. “Carbonation” of concrete is defined as the chemical reaction between the products of hydration of the concrete and the CO2 present in the atmosphere [1].

Ca_2+ (aq) + 2(OH^-) (aq) + CO_2 (aq) = C_aCO_3 (s) + H_2O

Carbonation is a physio-chemical reaction in which carbon dioxide gas try to pass through a carbonated surface into the material to reach fresh concrete. Carbon dioxide is the most present gas in environment and can form both as bicarbonates or carbonates and CO2 gas in dissolved form when reacts with water. So, the issue is mainly about the comprehensibility, probability and mode of entrance in the concrete surface. Due to this rate of carbonation changes greatly, so the uptake of carbon dioxide gas will rely mainly on the concrete type as well as the concreting atmosphere [2].

A. Carbonation

The reaction mechanism is quiet important for everything, as it will control the changes of the structure of carbonated shell. The carbonation mechanism that will occur in the saturated phase depend both up on the solubility and speed of diffusion. Generally the speed of carbonation depends on the humidity present in the concrete. Thus there is an optimum limit where the speed of carbonation is at maximal which in turn dependent up on the porosity of the carbonated layer. Carbonation also depends up on the composition and cement content used in the concrete [3]. Addition of mineral admixtures like fly ash would increase the carbonation resistance but requires long periods of curing. Most of the concrete structures present in moderately humid and hot climates usually suffer more from carbonation [4].

The carbonation rate mainly depends upon the porosity as well as water content present in the concrete. The diffusivity of the carbon dioxide relies on the pore arrangement of solidified cement and furthermore the condition of exposure [5]. The pore arrangement of concrete for the most part relies on the sort and substance of folio, water/cement proportion and level of hydration. There are certain factors that are affecting the concrete carbonation such as relative humidity, concentration of CO_2 in the atmosphere, mix proportions, material characteristics etc.,

The carbonation makes the plain concrete more durable because it makes the concrete totally dense, decreases the whole porosity, increases the sulphate resistance and alkali aggregate resistance but in reinforced concrete the value of pH will fall from 13.5 to 8.3 due to this reason the steel losses its passivity which in turn leads to corrosion as well as cracking and concrete spalling [6].

2. Methodology

The materials that are used for the preparation of the concrete in this project are cement, aggregates (finer and coarser), water as well as fly ash. Normal ordinary Portland cement of grade 53 is used. The specific gravity is 3.12. Locally available crushed rock materials are used as coarse aggregates. The size generally used is in between 10 mm and 20 mm. Locally available sand passing through IS sieve of size 4.75mm are used. Tap water free from impurities was used for mixing. Class F fly ash was used as a supplementary cementitious material in this study. Fly ash was used as the partial replacement of the cement with a percentage of 5%, 10%, 15%, 20%, 25% and 30%.

Design mix proportions has been found for the concrete mix design of M30 grade as per IS: 10262 was 0.5:1:2:3 (W: C: FA: CA) by weight.

A. Compressive strength

Strength of concrete is commonly considered its most valuable property. Strength usually gives the other all pictures of quality of concrete because strength is directly related to structure of the hardened cement paste. Concrete cubes were prepared of size 150mm*150mm*150mm and are kept for 28 days curing. For every percentage 6 cubes were prepared among them 3 cubes were carbonated and remaining are non-carbonated. So total number of cubes prepared were 42. After curing the cubes were tested in compressive strength testing machine. Both the carbonated and non- carbonated cubes were compared [9].

Fig. 1. Casted cubes

B. Porosity

The porosity of concrete is generally measured by many methods such as mercury intrusion porosymetry, pycnometry method etc., among them the pycnometry method is one of the feasible and easy methods to perform the test. The weights before the curing and after the curing as well as after carbonation were measured. From those values the absolute density and bulk density were calculated for the respective cubes. The porosity is calculated from the below

Porosity (%) = (1-bulk density/absolute density)*100

The porosity of the both carbonated and non-carbonated cubes were calculated and compared.

C. Accelerated carbonation chamber

Carbonation chamber was connected to CO_2 gas cylinder through the pipe. Carbonation chamber was fabricated in such a way that it was air tight with a top cover that was removable for placing and taking out the concrete specimens. The accelerated carbonation chamber was prepared with thick acrylic sheet; thickness of 6 mm. Size of the chamber is kept as 1m x 0.8m x 0.3m. The carbonation chamber was fabricated and was affixed to the CO_2 gas cylinder through 14 mm diameter nylon pipe.

A perforated platform was fabricated at height of 0.06 m from bottom of the chamber to avoid direct contact between the concrete specimens and salt solution. A saturated laboratory reagent grade sodium chloride salt solution was kept below this perforated platform in the chamber to maintain the required relative humidity. Saturated sodium chloride solution is used to maintain relative humidity of 50% as specified in the ASTME 104.

Fig. 2. Accelerated carbonation chamber

D. Carbonation depth

The carbonated cubes were broken and fractured surface was cleaned properly. Then the phenolphthalein indicator solution was sprayed on the fractured surface. Carbonated area remains color less where as non-carbonated area changes to purple red. The depth of carbonation was measured using the Vernier calipers.

E. Carbonation coefficient

For finding the value of carbonation coefficient the Fick’s first law of diffusion was used. By using the acquired depth of carbonation values we have calculated these values.

$dc = K\sqrt{t}$

Where, dc = depth of carbonation

K = carbonation coefficient (a constant)

t = exposure duration (here 28 hours)

3. Results and discussion

A. Compressive strength test

Table 1
Compressive strength test

% Fly Ash	Non-Carbonated Compressive Strength(MPa)	Carbonated Compressive Strength(MPa)
0	32.813	33.481
5	34.461	35.620
10	36.593	37.492
15	38.92	41.830
20	35.633	37.731
25	33.161	36.264
30	31.030	32.283

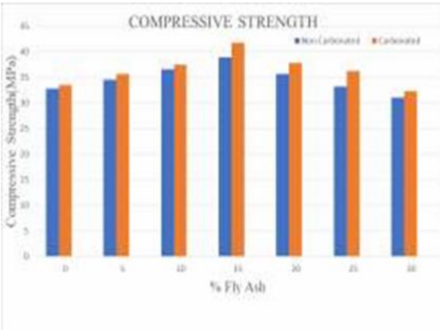

Fig. 3. Compressive strength graph

B. *Porosity test*

Table 2
Porosity test

% Fly Ash	Non-Carbonated Porosity (%)	Carbonated Porosity (%)
0	36.70	34.161
5	35.882	32.82
10	35.021	31.282
15	34.712	30.081
20	35.12	32.340
25	36.032	33.63
30	36.871	34.671

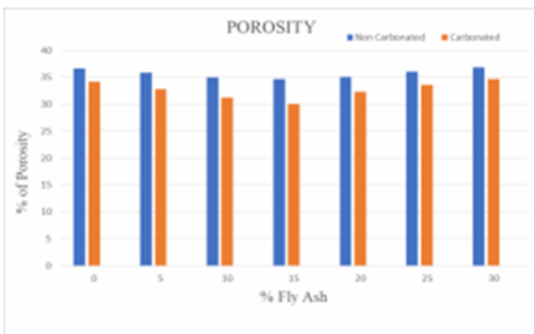

Fig. 4. Porosity test graph

C. *Carbonation depth*

Table 3
Carbonation depth

% Fly Ash	Carbonation depth (mm)
0	8.1
5	12.0
10	18.2
15	24.1
20	21.3
25	16.2
30	11.0

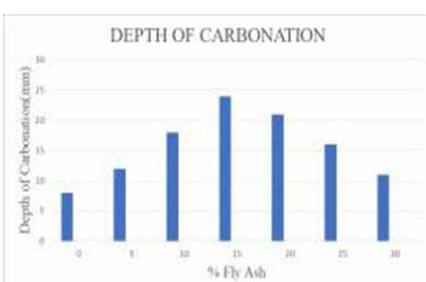

Fig. 5. Carbonation depth graph

D. *Carbonation coefficient*

Table 4
Carbonation coefficient

% Fly Ash	Carbonation Coefficient
0	7.41
5	11.11
10	16.7
15	22.2
20	19.4
25	14.812
30	10.2

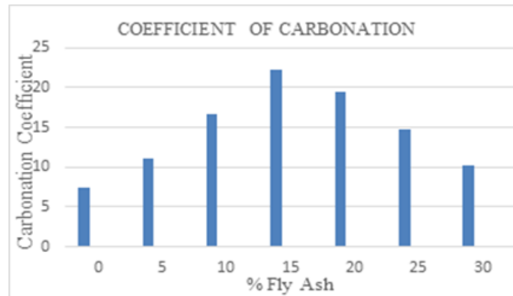

Fig. 6. Carbonation coefficient graph

4. Conclusion

The compressive strength of the carbonated cubes is quiet greater than the non-carbonated cubes because calcium carbonate occupies a greater volume than the calcium hydroxide. The strength of the cubes is increased up to 15% fly ash but later the strength got gradually decreased. The porosity got decreased due to carbonation up to a limit of 15 % FA and again increased because CO_2 can't diffuse easily in to the dense concrete. The depth of the carbonation is increased because of the addition of fly ash.

References

[1] Shaik Hussaina, DipenduBhuniab and Shamsher B. Singh, "An Experimental Investigation of Accelerated Carbonation on Properties of Concrete", Engineering Journal, Volume 20, Issue 2, 18 May2016.
[2] T. Chandrasekaraiah, H.Anantharam, Krishnamurthy M, K.V. Manjunath, M.N. Hegde, "Accelerted Testing of Deteriorated Concrete Structures due to Carbonation", International Journal of Research in Engineering and Technology, Volume-3, Special Issue: 06, May-2014.
[3] E. Chávez-Ulloa1,R. Camacho-Chab, M.Sosa-Baz, P. Castro-Borges and T.Pérez-López, "Corrosion Process of Reinforced Concrete by Carbonation in a Natural Environment and an Accelerated Test Chamber", International Journal of ELECTROCHEMICAL SCIENCE, Volume 8,2013.
[4] Alberto A. Sagiies, "Carbonation in Concrete and Effect on Steel Corrosion", University of South Florida, August 1993 - February1997.
[5] BjörnLagerblad, "Carbon dioxide uptake during concrete life cycle – State of the art", Swedish Cement and Concrete Research Institute, December2005.
[6] Manish Kumar and JituKujur, "Accelerated Carbonation Test on Concrete Made with Micro-Silica", International Conference on Recent Trends and Challenges in Civil Engineering, December 12-14, 2014.
[7] R.R.Hussain, and T. Ishida, "Critical Carbonation Depth for Initiation of Steel Corrosion in Fully Carbonated Concrete and Development of Electrochemical Carbonation Induced Corrosion Model", International Journal of Electrochemical science, V. 4, pp. 1178-1195, 2009.
[8] D. C.Atis, "Accelerated Carbonation and Testing of Concrete Made With Fly Ash", Construction and Building Materials, V. 17, pp. 147–152, 2003.

[9] C. F. Chang, and J. W. Chen, "The Experimental Investigation of Concrete Carbonation Depth", Cement and Concrete Research, V. 36 No. 9, pp. 1760–1767, 2006.
[10] N Venkat Rao and T Meena "A review on carbonation study in concrete" IOP Conf. Series: Materials Science and Engineering 263 (2017).
[11] Lakhwinder Pal Singh and Jagtar Singh, Effects Of Cryogenic Treatment On The Cutting Tool Durability, International Journal of Design and Manufacturing Technology (IJDMT), Volume 3, Issue 1, January-December (2012), pp.11-23.
[12] T. Jena and K. C. Panda, Compressive Strength and Carbonation of Sea Water Cured Blended Concrete. International Journal of Civil Engineering and Technology, 8(2), 2017, pp. 153–162.