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Experimental investigation of carbonation in reinforced concrete structure due to corrosive environment

Shubham Gopal Chopkar[1, a)] and Prof. Deepa Telang[2, 3, b)]
[*1]PG Student M-Tech Structural Engineering, G. H. Raisoni Institute of Engineering & Technology, Nagpur, India.
[*2] Assistant Professor, G. H. Raisoni Institute of Engineering & Technology, Nagpur, India.

Author Emails
a)shlok.chopkar1432@gmail.com
b)deepa.telang@raisoni.net

Abstract. Concrete is one of the most important materials that is being used next to water on the earth for the purpose of construction. It has innumerable uses in our day to day life. Generally for every material deterioration is the quiet happening phenomenon, in the same way the concrete also deteriorates in three main forms like physical, chemical and corrosion. The carbonation is widely recognized as a notable cause of corrosion of reinforcement present in concrete. This paper mainly investigates the carbonation effect on the concrete properties such as compressive strength, porosity and durability. The incorporation of Fly Ash (FA) is better known to improve the durability of reinforced concrete which are supplementary cementitious materials. In this study concrete cubes are prepared with and without the partial replacement of cement by Fly Ash and are placed in an accelerated carbonation chamber to study carbonation of concrete. Basically the concrete cubes are prepared for M30 grade with different percentages of FA like 0%, 5%, 10%, 15%, 20%, 25% and 30%. This paper also presents the experimental results of the work carried out on carbonated and non-carbonated concrete with CO2 concentration and exposure period like compressive strength, porosity, depth of carbonation and coefficient of carbonation.

IndexTerms – Concrete, Reinforcement,corrosion, Critical carbonation content, Durability, Modeling, carbonation attack, Fly Ash, Durability, Reinforced Concrete.

I. 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. Steel corrosion in concrete is a major deterioration problem occurs due to carbonation and presence of chloride ions at reinforcement level. “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].

$Ca^{2+} (aq) + 2(OH^-) (aq) + CO_2 (aq) = CaCO_3 (s) + H_2O$

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. The rate of carbonation slows down because carbon dioxide needs to pass through a thickening layer of its varied products. Dry concrete does not carbonate because of the deficiency of water that is needed for ions to form and later react to form calcite [2]. In contrast carbonation is very gradual in wet conditions. Generally, carbonated concrete is hard and stable so carbonation will not endanger the stability of the concrete i.e., its strength. Mostly the concrete structures are reinforced which may rust when the carbonation of concrete occurs [3].

II. LITERATURE REVIEW

1. **"Some effects of cement and curing upon carbonation and reinforcement corrosion in concrete" L. J. Parrott** , The results also suggested that estimation of the rate of reinforcement corrosion could be improved by taking account of the cement type and treating the un-neutralised remainder as a variable.

2. **"A The Useful Life of Reinforced Concrete Structures with Reinforcement Corrosion Due to Carbonation in Non-Aggressive and Normal Exposures in the Spanish Mediterranean" , Sergey E. Barykin.** This significant deviation shows the need for a revision of the Spanish EHE 08 regulation, which should include aspects such as the action of dampness by capillarity and the differences in electrochemical potential between the different materials.
3. **"Ambient pressure carbonation curing of reinforced concrete for CO_2 utilization and corrosion resistance",** XiangpingXian[a]DuoZhang[b]HanLin[a]YixinShao[a]**,** The IC-accelerated corrosion test verified that carbonation curing improved the concrete resistance to chloride penetration by lowering the current and inhibiting the corrosion-propagation, leading to an enhanced structural integrity and an extended service life after corrosion initiation.
4. **"Evolution of ITZ and its effect on the carbonation depth of concrete under supercritical CO_2 condition,** In this paper, supercritical carbonation tests of concrete specimens with different water-to-cement ratios are carried out. In the test, the thickness of interfacial transition zone (ITZ) of the concrete is determined by the distribution of Ca/Si ratio across the interface between the coarse aggregate and cement paste.
5. **"Carbonation study in concrete", N Venkatrao and T meena.** In this studythe carbonation test on structure were found naturally and compressive strenghth is measured.
6. **"Effects Of Cryogenic Treatment On The Cutting Tool Durability", Lakhwinder Pal Singh and Jagtar Singh.** This study cryogenic processing can improve the service life of tools, the degree of improvement experienced and the underlying mechanism remains ambiguous. The steps involved in cryoprocessing are critical enough to account for the significant incongruity in posttreated performance.
7. **"Experimental Evaluation of the Durability Properties of High Performance Concrete Using Admixtures", M. Vijaya Sekhar Reddy, Dr.I.V. Ramana Reddy and N.Krishna Murthy.** In this research main objective of this experimental work is to analyse the effect of recycled aggregates (RA), on the basis of the study of the various qualities, of the physical, mechanical and durability properties of High Performance Concrete (HPC).
8. **"Compressive Strength and Carbonation of Sea Water Cured Blended Concrete.", T. Jena and K. C. Panda.**This paper investigates the influence of sea water on pre-cast concrete containing industrial by-product materials such as fly ash (FA) and silpozz. The mix design is targeted for M30 grade concrete. Ten concrete mixtures were designed to have the same degree of workability with water to cementitious material ratio of 0.43.

III. MATERIALS USED

Materials used in the experimental program

1. Ordinary port land cement: 53 grade

2. Fine aggregate : River sand

3. Coarse aggregate : less than 20mm 4. Water 5. Fly ash Properties of the materials used

2.1. Cement Normal ordinary Portland cement of grade 53 is used. The specific gravity is 3.12. 2.2. Coarse aggregate Locally available crushed rock materials are used. The size generally used is in between 10 mm and 20 mm. A Pravalika and N Venkat Rao http://iaeme.com/Home/journal/IJCIET 1607 editor@iaeme.com 2.3. Fine aggregate Locally available sand passing through IS sieve of size 4.75mm are used. 2.4. Water Potable water was used for mixing. 2.5. Fly ash 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%.

METHODOLOGY

1. Compressive strength test

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.

2. 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 method 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 [10]. The porosity is calculated from the below formula:- Porosity (%) = (1-bulk density/absolute density)*100 The porosity of the both carbonated and non-carbonated cubes were calculated.

3. Accelerated carbonation chamber

Experimental set up consists of carbonation chamber, CO2 gas cylinder. Carbonation chamber was connected to CO2 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 [11]. Effect of Carbonation on the Properties of Concrete http://iaeme.com/Home/journal/IJCIET 1608 editor@iaeme.com 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 CO2 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 ASTM E 104. Figure 2 Accelerated Carbonation Chamber

Fig: Accelerated carbonation chamber

4. Depth of carbonation

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 colorless where as non-carbonated area changes to purple red. The depth of carbonation was measured using the Vernier calipers. 3.5. Coefficient of carbonation 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 = Coefficient of carbonation, a constant t = duration of exposure

Observation: Observation and calculation of various results

IV. 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 CO2 can't diffuse easily in to the dense concrete. The depth of the carbonation is increased because of the addition of fly ash.

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[3] XiangpingXian[a]DuoZhang[b]HanLin[a]YixinShao[a] Department of Civil Engineering, McGill University, 817 Sherbrooke Street West, Montreal, QC H3A 2K6, Canada 2. Department of Civil and Environmental Engineering, University of Michigan, 2350 Hayward Street, Ann Arbor, MI 48109, United States

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