

An Experimental Study for Microstructure changes by Carbonation on the NPP Concrete Structures

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1. Introduction

One of the most important deterioration mechanisms of concrete is that caused by the neutralization of the cement matrix. For this reason, the carbonation of concrete, as consequence of its interaction with the atmospheric carbon dioxide (CO₂), has been considered for years a subject of interest in researches of cement chemistry. The carbonation process is a complex physicochemical process that slowly modifies the structures of the concrete in the course of time and induces changes into its chemical and physical properties [1].

2. Experimental Work

2.1 Carbonation Environment

The scope of this study was to investigate the carbonation of NPP (Nuclear Power Plant) concrete. The effects of the NPP concrete mixture on the physical properties of concrete and the alteration of the microstructure of the cement paste due to exposure to carbon dioxide were included in this investigation.

It is known that the process of carbonation is actually a long-term reaction. Therefore, an accelerated carbonation testing system has to be used to carbonate the concrete in short term. The accelerated carbonation system was constructed to expose the concrete to an equivalent environment [2].

In this study, the relative humidity of the system was maintained by the dehumidifier which consists of a cooling unit. A timer was also used to control the total system. The timer switched the total system on for 3 hours and switched the total system off, for 3hours continuously. This kept the relative humidity at 60±5% in the system, The temperature of the system was controlled by keeping it in a room with 20°C constant temperature. The system containing 5%CO₂ and 20%O₂ in Nitrogen was used for the study [3].

2.2 Mix Proportion

Mix proportions of NPP concrete are shown in Table 1. Fly ash with replacement level of 20% was used. A water-binder ratios (w/b) of 0.40, 0.45 and 0.50 were adopted for NPP concrete.

Table I: Mix Proportion of NPP concrete

	W/B	Cement (kg/m ³)	Fly ash (%)	Coarse aggregate (kg/m ³)	Fine aggregate (kg/m ³)
Mix1	0.40	327		945	753
Mix2	0.50	262	20%	945	827
Mix3	0.45	298		978	735

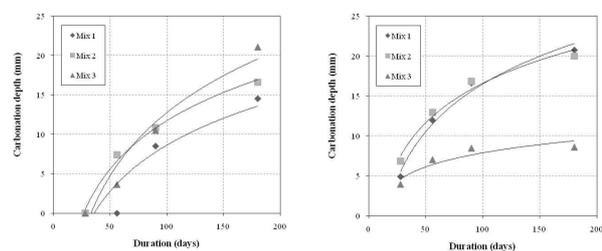
Cylinders of 100mm in diameter × 200mm in height were cast for determination of compressive strength [4]. Cube mortar specimens of 50mm×50mm×50mm were cast for determination of carbonation, and equivalent size specimens of cement paste were cast for microscopic examinations as a MIP (Mercury Intrusion Porosimetry) and SEM (Scanning Electron Microscope). After standard curing for 28days, the specimens were exposed to carbon dioxide.

The accelerated carbonation test was carried out with specimens at different exposure durations. The test was initiated at 28, 56, and 180days from first day of an exposure to carbonation.

3. Results and Discussion

3.1 Carbonation Depth

To monitor the depths of carbonation, freshly broken pieces of hydrated cement paste were sprayed with phenolphthalein indicator solution, which changes from colorless below a pH value of approximately 9.2 to red above this pH value [5]. Thus, the depth from the exposed face at which a color change to red is just visible gives a simple indication of carbonation depth. All the specimens in a particular environment were deemed to be carbonated when sample specimens remained colorless throughout their thicknesses after the phenolphthalein test.



(a) Cement paste

(b) Mortar

Fig. 1. The carbonation depth with exposure duration.

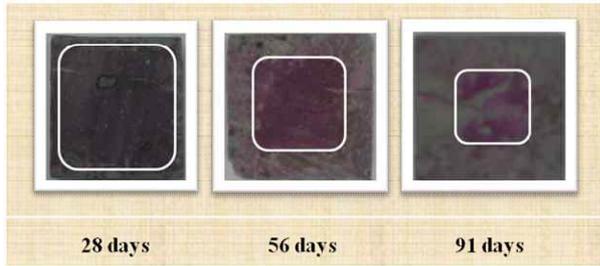


Fig. 2. Depth changes cause by carbonation of cement paste.

3.2 SEM & MIP

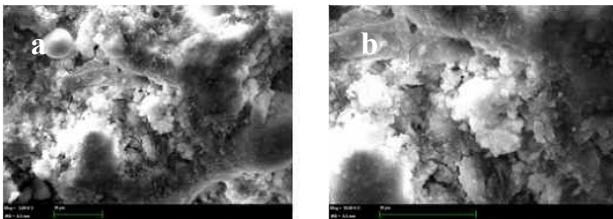


Fig. 3. SEM images of (a) 5000x magnification, (b) 10000x magnification..

Fig. 3 shows a scanning electron microscopy (SEM) micrograph of the interior of a mortar for 180days aggregate is lightly covered with atmospheric calcium carbonate

Fig. 4 shows a typical cumulative mercury intrusion/reaction curve for carbonated for 28days and carbonated mortar for 180days.

The pore size distribution as measured by mercury intrusion porosimetry is as shown in Fig. 4, 0.12% of the pores in the cement paste of 28days are larger than 1 μm , compared with 0.08% of the cement paste of 180days. It is these larger pores which offer the greatest access to atmospheric CO_2 .

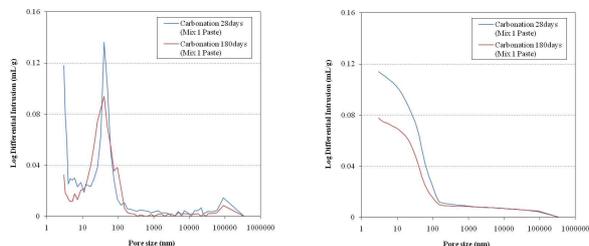


Fig. 4. MIP results of (a) distribution of pore structure, (b) total pore volume.

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