DEVELOPMENT OF AN ECONOMICAL CHAMBER FOR ACCELERATED CARBONATION TESTING OF CONCRETE

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ABSTRACT—Carbonation has affected the concrete structures all over the world. Carbonation takes decades to act upon concrete, so it is need to limit the period of carbonation and find the results of carbonation in a short span of time using accelerated techniques.In this paper an economical accelerated carbonation chamber is constructed using ready at hand available materials. Artificial environment was created inside the chamber with specific temperature and humidity. Carbon dioxide of higher percentage was induced into the chamber using carbon dioxide cylinders. Further cost analysis of the accelerated carbonation chamber was done.

KEYWORDS—*Carbonation, concrete, accelerated tests, relative humidity, pore systems, water-cement ratio.*

I. INTRODUCTION

Carbon dioxide is a greenhouse gas which is present in the environment and is on the rise over the several years. Carbonation is a process in which the carbon dioxide (CO_2) present in an environment

diffuses into the concrete and reacts with its ingredients calcium hydroxide ($Ca(OH)_2$) and CSH resulting in the formation of calcium carbonate ($CaCO_3$).[1]Calcium carbonate is a precipitate which weakens the concrete.

$$CO_2+Ca(OH)_2 \Rightarrow CaCO_3+H_2O$$[12]

Naturally carbonation takes many years to act on concrete as it is present in around 400ppm – 450 ppm in a natural environment. Various factors are dependent on progress of carbonation of concrete such as temperature, hydration, cracking, pore structure, etc. The most favorable condition for the carbonation progression is when temperature is at room temperature (25^0C – 30^0C) humidity is (65% - 75%).[3]Carbonation deteriorates concrete as it affects its strength. The process starts with the surface of concrete and then it slowly penetrates with time into the concrete. The slowly advancing carbonation results in the reduction of pH level of concrete. Carbon dioxide which reacts with calcium hydroxide ($Ca(OH)_2$) is present in 25% - 45% by weight in cement. Concrete which is alkaline in form (pH- 12.6-13) when reacts with carbon dioxide results in the reduction of pH level (pH<9).[10] This fall in pH level is further responsible for the initiation of depassivation phenomenon of rebar embedded in concrete. Ultimately this results in total failure of a structure as a whole.[10]

Factors affecting carbonation of concrete:

1. Carbon Dioxide present in air is responsible for carbonation.
2. Percentage of humidity present in environment.
3. Water-cement ratio.
4. Pore systems of hardened concrete.
5. Temperature of the surrounding.

II. OBJECTIVES, SCOPE AND LIMITATIONS

The objectives of this study are as follows:

i. To construct an economical chamber using readily available materials.
ii. Cost analysis of accelerated carbonation test chamber.

Scope of this study:

- Construction of an economical chamber for accelerated carbonation testing of concrete. Construction of chamber to limit the time period of carbonation of concrete.

Limitations:

i. Can accommodate only 8 concrete cubes of size 150*150*150 mm
ii. Carbon dioxide sensor cannot measure carbon dioxide more than 5% Volume of chamber

III. METHODOLOGY

A. Materials and components

a. Carbon dioxide Sensor

MH-Z16 carbon dioxide sensor is used. This sensor has high sensitivity and resolution with analog voltage signal and PWM wave output. It has a linear output with temperature compensation.

The measuring range of this sensor is 0-50000 ppm. Operating voltage is 5V. It has working condition in temperature upto 50^0C and humidity upto 95% RH.

b. Thermo-hygrometer

It is a digital meter showing temperature, humidity, time and calendar. Is has two modes of temperature showing in ^{0}C or ^{0}F. Two modes of timing viz. 12 hours and 24 hours with alarm function. It has working condition in temperature up to 50^0 C and humidity up to 95% RH.

c. Enclosed chamber

An enclosed steel chamber of dimension 520mm * 40mm * 1220mm is used for the testing of concrete specimens. Front door is glass gazed for sunlight simulation.

d. Carbon dioxide cylinders

Carbon dioxide cylinders are used for the induction of carbon dioxide in the enclosed chamber. The carbon dioxide cylinders had knob to regulate the supply manually.

B. Accelerated Carbonation Test Chamber

The accelerated carbonation test chamber consists of a single enclosed steel chamber as shown in the figure 1. The chamber has two inlet; one for carbon dioxide induction and the other for humidity inlet. The chamber is easily constructed using steel chamber of (142 liters- internal dimensions). M-seal and silicon was used to make the system air tight. The chamber is given a supply of carbon dioxide of 45000 ppm or 4.5%. The relative humidity was maintained at 65% to 75% and temperature of 25^0C to 30^0C with natural sunlight simulation.

Relative humidity was controlled using vaporizer with a manual knob. Vapor was introduced in to the chamber only when the humidity level fell below 65% RH. Precautions were taken to avoid losses of vapor by sealing the chamber with m-seal and silicon. The vapor introduced pipe had holes in them for free circulation.

Temperature was controlled using natural sunlight simulation. Also a room heating coil was used in case of no sunlight and when the temperature fell below 25^0C.

The carbon dioxide was introduced in to the chamber using compressed carbon dioxide gas cylinders. Manual control knob to cylinders were provided to regulate the supply. The carbon dioxide introduced pipe had holes in them for free circulation. In this experiment 45000 ppm or 4.5% carbon dioxide atmosphere was chosen to accelerate the effect and limit the test period. However there was fluctuation in the percentage of carbon dioxide in the chamber. This was overcome by introducing carbon dioxide manually using a controlled knob.

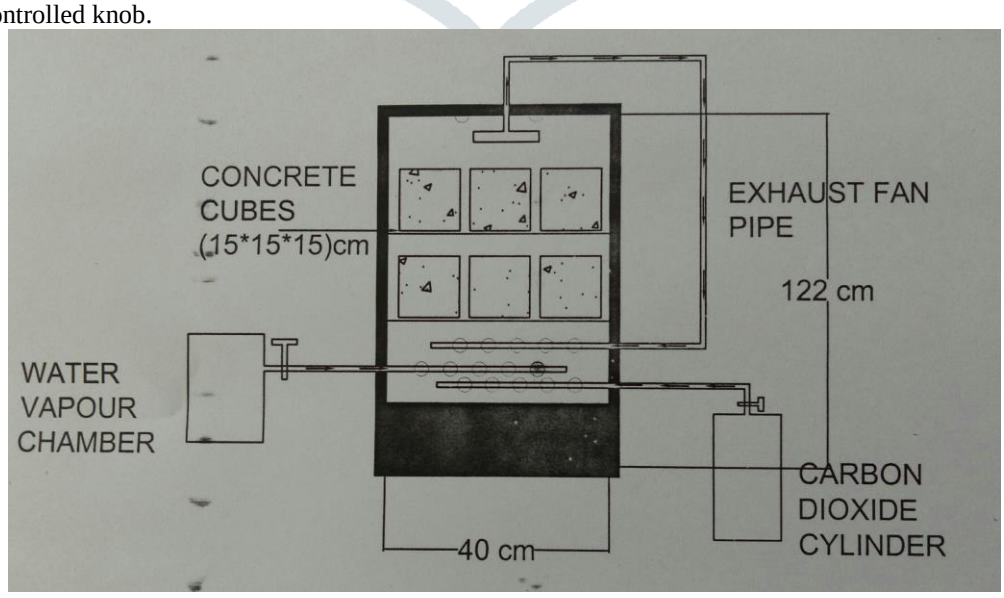

Fig No. 1 Accelerated Carbonation Test Chamber

Air was circulated in the chamber using SMACC fan. It was mounted on top of the chamber. The pipe circulated air from top to bottom. Air circulation using fan was used to avoid saturation of gas and vapor in the chamber.

For the placing of concrete specimens two steel racks were used. Sufficient distance was maintained between the two racks for proper circulation of carbon dioxide and vapor.

IV. RESULT AND DISCUSSION

The accelerated carbonation test chamber was designed and then constructed. The entire cost of materials and components used for construction was approximately 7500 INR.

Cost analysis done:

i. Carbon dioxide sensor- 3000 INR
ii. Hygro-thermometer- 800 INR
iii. Carbon dioxide cylinder- 700 INR
iv. Enclosed steel chamber- 1500 INR
v. Vaporizer- 500 INR
vi. Miscellaneous- 1000 INR

All the materials used were available in the vicinity of Pune city. The test chamber was experimented for a day and found negligible losses.

The m-seal and silicon sealing along with magnetic door were found effective to prevent any leakages through chamber, though it was not 100% effective. Data collection is manual by taking photographs at an interval of 3 hours under the CCTV footage. Automatic data logging is considered for the future scope.

V. CONCLUSION

A cost effective economical chamber was constructed using readily available materials. The accelerated test chamber is useful for the study of carbonation on concrete specimens. An accelerated chamber to accommodate 8 concrete blocks of 150*150*150 mm was constructed.

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