Cement & Concrete Composites 34 (2012) 924–930

Contents lists available at SciVerse ScienceDirect

Cement & Concrete Composites

journal homepage: www.elsevier.com/locate/cemconcomp

Carbonation in concrete infrastructure in the context of global climate change – Part 1: Experimental results and model development

S. Talukdar [a,*], N. Banthia [a], J.R. Grace [b]

[a] Department of Civil Engineering, University of British Columbia, Vancouver, Canada
[b] Department of Chemical and Biological Engineering, University of British Columbia, Vancouver, Canada

ARTICLE INFO

Article history:
Received 18 October 2011
Received in revised form 21 April 2012
Accepted 24 April 2012
Available online 15 May 2012

Keywords:
Concrete
Carbonation
Degradation
Modeling
Long term performance

ABSTRACT

There is nearly unanimous consensus amongst scientists that increasing greenhouse gas emissions, including CO_2 generated by human activity, are effecting the Earth's climate. Increasing atmospheric CO_2 emissions will likely increase the rates of carbonation in reinforced concrete structures. However, there is a lack of reliable models to predict the depth of carbonation as a function of time.

To address this deficiency, a numerical model involving simultaneous solution of the transient diffusion and reaction equations of CO_2 and $Ca(OH)_2$ was developed. The model successfully includes the effects of variations in various properties such as porosity, humidity, temperature, atmospheric CO_2 concentrations and chemical reaction rates.

The applicability of the model was confirmed after calibration using data from accelerated carbonation experiments, and the model is used to evaluate the possible effects of climate change by inputting various future climate scenarios in Part 2.

© 2012 Elsevier Ltd. All rights reserved.

1. Introduction and background

The world's climate is undergoing significant changes, with the effects of these changes expected to be quite profound over the course of this century. The Earth's average temperature has increased by 0.5 °C since the 1970s and is expected to increase by a further 1.4–5.8 °C by the end of this century [1]. Many of the effects of climate change, including temperature change, increase in pollutant concentrations, changes in relative humidity, precipitation, wind patterns, and frequency of severe events (meteorological phenomenon with the potential to cause significant damage, serious social disruption, or loss of human life), could have significant impacts on infrastructure lifespan. Infrastructure capacity could be overwhelmed (rg. dikes failing due to increased sea levels), or it could be degraded (i.e. increased erosion due to extreme weather events). Assessing the impact is difficult, as the relationship between degradation and climate is complex [2]. A concise summary of possible effects of climate change on building materials was provided by Nijland et al. [3].

Limited work has been carried out on the effects that global climate change may have on concrete infrastructure, mainly because the issue has only been recently recognized. Increases in carbonation rates of reinforced concrete structures are expected as a result of increased temperatures and CO_2 concentrations. Two studies in particular are noteworthy. Yoon et al. [4] were the first to consider the effects of climate change on concrete, in particular the effect on carbonation rates. A simplified model was proposed based on a $t^{0.5}$ relationship between time and carbonation depth. While this provides a reasonable approximation, it fails to account for the finite depth and reaction effects. Moreover, this model does not account for the influence of temperature change, which can significantly affect the diffusion coefficient of CO_2 into concrete, the rate of reaction between CO_2 and $Ca(OH)_2$, and the rate of dissolution of CO_2 and $Ca(OH)_2$ in pore water. In addition, the model is a point-in-time predictive model, which assumes CO_2 concentrations to be constant up to a given time, thereby overestimating carbonation depths [5]. Stewart and Ping [5] continued the earlier work by Yoon et al. [4] by taking into account the effect of temperature on the diffusion coefficient, but they did not consider the influence of temperature on the other aforementioned parameters. Their work looked not only at carbonation, but also at the time to crack initiation, crack propagation and failure due to reinforcement corrosion. They also used the same carbonation model as Yoon et al. [4] in their work, but noted that there is a need for an improved model that considers the time-dependent effect of CO_2 concentration and other parameters such as temperature and humidity.

This paper is part of a study being carried out at the University of British Columbia focusing on the effects of global climate change and increasing CO_2 concentrations on the deterioration of reinforced concrete, in particular on rates of carbonation-induced corrosion, with the goal of providing a comprehensive risk assessment

* Corresponding author.
E-mail address: sudip@civil.ubc.ca (S. Talukdar).

0958-9465/$ - see front matter © 2012 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.cemconcomp.2012.04.011

of structural degradation to concrete infrastructure. While the wider study looks at the entire lifespan of a given specimen from initiation of carbonation, to initiation of corrosion, to cracking, spalling, and ultimate failure, the scope of Part 1 of this paper is limited to experimental verification and model development of the carbonation phase of deterioration.

2. Experimental materials and procedure

Tests were performed to accurately measure the carbonation depth under conditions of varying CO_2 concentration, temperature and humidity. To generate these data, concrete specimens were cast, cured, and subjected to accelerated carbonation testing in an ESPEC PR4-KPH carbonation chamber manufactured by ESPEC North America Inc. This chamber was able to electronically control CO_2 concentration, temperature, and relative humidity. Concrete prisms of dimensions 100 mm × 100 mm × 350 mm were cast, allowed to cure in a water bath for 28 days, removed from the bath and then allowed to come to equilibrium with laboratory conditions (20 °C, 60% *RH*) over a further 28 days before being placed in the carbonation chamber. There are currently no standards which specify the drying/conditioning period for carbonation tests. However, based on a review of experimental setups in studies by previous researchers [6–8], it is believed that the conditioning time employed is sufficient to achieve a uniform humidity profile in the concrete cover.

Two types of concrete were tested. One was a virgin, uncontaminated mix, while the other was a chloride-contaminated mix (0.5%/wt. of cement). The contaminated mix was selected to determine whether the presence of chlorides would affect the carbonation progress. For each of the mixes, the slump was maintained at 200 mm and the air content was maintained between 5% and 8%. The mix design is given in Table 1:

Samples were subjected to four different laboratory scenarios, with each scenario running for 8 weeks. The scenarios were selected to evaluate the effect of time for each individual atmospheric variable (CO_2 concentration, temperature and humidity) on carbonation progress. For each type of mix, and for each scenario, five prisms of concrete were cast. This provided a total of 40 prisms cast and subjected to carbonation testing over the course of the study. The scenarios are described in Fig. 1.

For Scenarios B, C and D, Temperature, Relative Humidity, and CO_2 concentration respectively were increased at constant rates over the duration of the scenario. This is mathematically expressed in Table 2. At 7-day intervals, the specimens were removed from the chamber, and sections 30 mm thick were sawcut from each block. Each section was then sprayed with a solution of 1% phenolphthalein in 70% ethyl alcohol. The areas which had been carbonated remained clear in color (pH < 9), whereas uncarbonated areas turned purple (pH > 9). The depth of carbonation could then be determined by averaging the depth along the perimeter of the carbonation front at 12 different locations. A sample section is shown in Fig. 2:

Table 1
Uncontaminated mix design (m^3).

Type 10 portland cement	380 kg
Water	190 kg
Coarse aggregate	800 kg
Fine aggregate	850 kg
Air entrainment Admixture	150 mL

Table 2
Formulas for increases in variables with time.

Scenario B	$T(t) = 25 + (20/56)t$	T: Temperature (C), t: Time (days)
Scenario C	$H(t)=50 + (40/56)t$	H: Relative humidity (%), t: Time (days)
Scenario D	$C(t)=6 + (4/56)t$	C: CO_2 Concentration (%), t: Time (days)

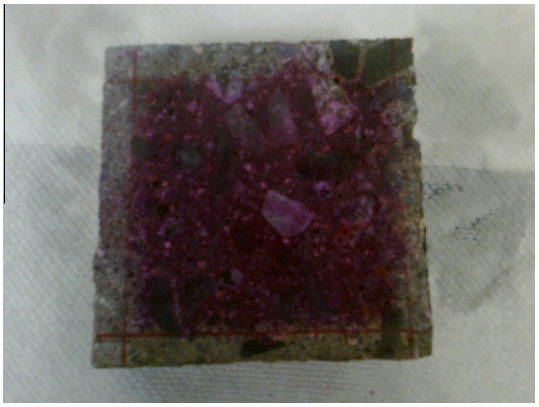

Fig. 2. Carbonated concrete section.

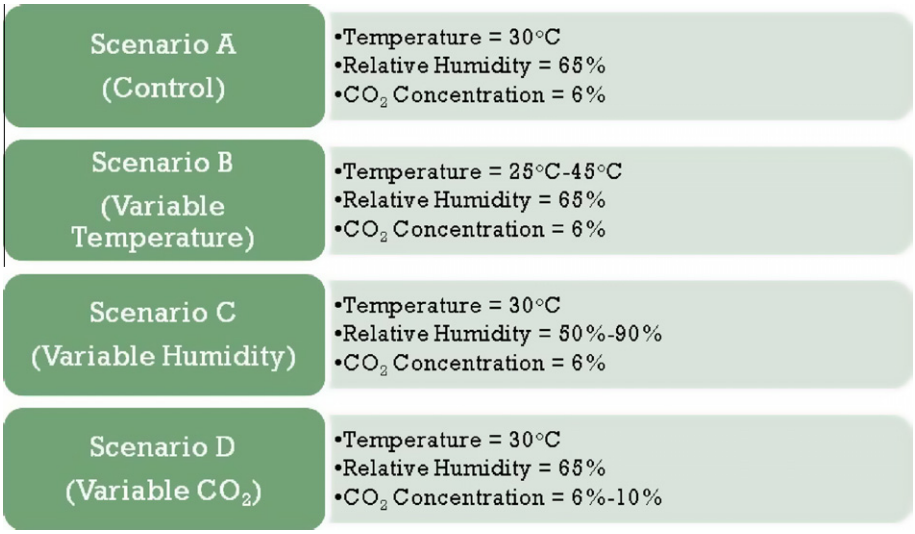

Fig. 1. Laboratory scenarios.

Download English Version:

https://daneshyari.com/en/article/1454839

Download Persian Version:

https://daneshyari.com/article/1454839

Daneshyari.com