Automation in Construction 20 (2011) 559–570

Contents lists available at ScienceDirect

Automation in Construction

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

Computer-aided oxygen transport model of mass and energy simulation for corrosion of reinforced steel

Raja Rizwan Hussain [a,*], Tetsuya Ishida [b,1]

[a] PO Box: 800, CoE-CRT, Civil Engineering Department, College of Engineering, King Saud University, Riyadh, 11421, Saudi Arabia
[b] Concrete Laboratory, Civil Engineering Department, The University of Tokyo, 7-3-1, Hongo, Bunkyo-ku, Tokyo, Japan

ARTICLE INFO

Article history:
Accepted 17 November 2010
Available online 18 December 2010

Keywords:
Oxygen
Corrosion
Automation
Modeling
Reinforced concrete construction

ABSTRACT

The paper includes automated modeling and experimental verification of corrosion in reinforced concrete construction under the effect of varying oxygen concentration. Various construction corrosion cells with different concrete compositions under four different environmental conditions (air dry, submerged, 95% R.H and alternate wetting–drying) have been investigated under controlled laboratory conditions. Using the results (half-cell potential and gravimetric corrosion mass loss) of these laboratory tests and an automated computer-aided simulation model based on mass and energy transfer through the porous construction media for the corrosion process, it was possible to predict, maintain and manage the influence of oxygen concentration on the corrosion rate of the reinforcement in concrete construction under various defined conditions satisfactorily. The variation in oxygen concentration available for corrosion reaction has been taken into account simulating the actual construction field conditions such as by varying concrete cover depth, relative humidity, water–cement ratio, etc. The modeling task has been incorporated by the use of an automated computer based construction durability model 'DuCOM' developed by our construction research group at The University of Tokyo as a finite element computational approach for the effect of oxygen on corrosion in relation to W/C, concrete cover, chloride concentration and various environmental humidity construction conditions. This paper is of interest to a broad readership for those interested in automation in reinforced concrete construction involving durability design & engineering related to corrosion of steel in concrete, corrosion resistant construction technology, corrosion maintenance & management. The scope of this paper encompasses various stages of the corrosion in construction life cycle from initial planning and design, through construction of steel reinforced concrete facility, its operation and maintenance, to the estimation of demolishing due to limiting oxygen controlled corrosion damage. This paper contains novel investigations involving computer-aided durability design, corrosion modeling under varying oxygen, classification and standardization of corrosion product data. The paper incorporates mass and energy process simulation models and graphics for the effect of oxygen on corrosion and its automated inspection as well as management. This comprehensive automated modeling and experimental investigation involving variety of materials and environmental variables will help in profound understanding, maintenance and management of oxygen controlled corrosion reaction in RC construction and will provide significant future research prospects in the field of oxygen limiting automated corrosion modeling of RC construction.

1. Introduction

Reinforced concrete construction corrodes under the effect of various environmental actions such as chloride, carbonation, temperature, etc. However, these environmental loadings can cause corrosion only if enough amount of oxygen is available in vicinity of corroding reinforcement bar in concrete construction. Therefore, it is necessary to understand and predict the automated effect of oxygen concentration variation on corrosion of RC construction. Many researchers have investigated the effect of oxygen on corrosion of RC construction [1–6]. In this research, qualitative as well as quantitative (for which the previous research data is limited) deep investigations have been carried out in order to clarify the involved mechanisms of corrosion under varying oxygen conditions by incorporating realistic and automated mass balance computer-aided modeling as well as multi variable laboratory controlled experimentation. Thus the objective of this research is determination and clarification of the limiting influence of oxygen on corroding steel in concrete as a function of relevant construction parameters (W/C ratio, cement content, cover thickness, chloride content, curing, etc.) and various environmental moisture conditions.

* Corresponding author. Tel.: +966 562 556969; fax: +966 1 4696355.
E-mail address: raja386@hotmail.com (R.R. Hussain).
[1] Tel.: +81 3 5841 6146; fax: +81 3 5841 6010.

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doi:10.1016/j.autcon.2010.11.022