This is a book that is essential for Engineers, Architects, and Scientist that work in the field of structural durability.

Life Cycle of CO_2 ($LCCO_2$) Evaluation and Service Life Prediction of RC Structure Considering Carbonation Degree of Concrete

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Abstract

Life cycle of CO_2 ($LCCO_2$) evaluation and service life prediction of RC structure considering carbonation degree of concrete.

Building structure standard was modified in KOREA in 2012 in order to activate green development and new technology such as eco-friendly material and high strength concrete to be adopted to building. Because recently concerns about the sustainability of the globe highlight the need of CO_2 reduction and eco-friendly building and each country make and plan to commit the financial obligations of CO_2 emissions. As a result, design should consider using low CO_2 emissions and resource and CO_2 display of products has expanded.

On the other hand, there is still no formalized way in KOREA to display CO_2 emission of concrete that is a main building material. Especially, quantitative evaluating method for it is needed because it can be used as a reference day to decrease CO_2 emission by replacing cement with admixtures in concrete. Because cement emits much CO_2 in the process of making it but admixtures emits CO_2 much smaller than cement. Besides, concrete can absorb CO_2 through carbonation but there is still no reference data in KOREA to consider it.

Concrete carbonation decreases durability of concrete because it causes rebar to corrode. Therefore, quantitative evaluating method for amount of CO_2 absorption through carbonation should be considered under the condition that carbonation does not affect durability of RC structure.

Evaluating service life by carbonation has a limit that it uses an indicator. But that method is a qualitative method and has a limit not to consider carbonation degree. In the case of salt damage, quantitative evaluation method can be possible by measuring chloride ion concentration at the depth of rebar location but in the case of carbonation there is still no quantitative evaluation method (evaluation materials, measurement position) and standard yet. Evaluation method by indicator has a qualitative assessment limit that instability color change may happen in the carbonation depth anytime. In addition, carbonation depth measurement method by the indicator has a problem that concrete color does not discolored in early progress of carbonation. Carbonation depth measurement method using an indicator may cause prediction error of service life of RC structure when measurement error by measurers has happened because of ambiguous boundary. Thus, evaluation method by indicator has a qualitative assessment limit that unstable color change may happen in the carbonation depth anytime. Therefore, a quantitative evaluation methods and standards for carbonation are required to overcome this problem.

So, this study proposed a quantitative evaluating method that overcomes the limitation of qualitative evaluation, which is carried out using the naked eye with respect to the color change boundary by spraying indicator. Carbonation depth becomes the basic data for estimating the residual life and durability of RC structures. To achieve this objective, the quantitative change of $Ca(OH)_2$ and $CaCO_3$ for each depth in concrete according to the carbonation process is measured using TG/DTA in order to propose a quantitative method and an evaluation basis. Another goal is to propose evaluating method of CO_2 absorption in the air through carbonation and how to evaluate $LCCO_2$ (emission – absorption of CO_2).

This study is composed of six chapters to evaluate $LCCO_2$ and service life prediction of RC structure considering carbonation degree of concrete and summarized contents of each chapter are as follows:

In chapter 1, necessity and objectives of this study are explained.

In chapter 2, review for carbonation and a quantitative evaluating method is

conducted to complement qualitative evaluating method by indicators.

In chapter 3, correlation between pH value and quantities of $Ca(OH)_2$, $CaCO_3$ is analyzed experimentally by carbonation weeks, concrete depths through accelerated carbonation experiment in order to propose a quantitative evaluating basis. Quantity of $Ca(OH)_2$ is important to predict service life of concrete against carbonation and cement hydration model can predict it quantitatively to any concrete mix. Therefore, validation for cement hydration model is verified by comparing prediction values and measured values of $Ca(OH)_2$.

In chapter 4, prediction model for carbonation based on FEM is used to predict the service life of RC structure. Required input parameters such as initial concentration of $Ca(OH)_2$, diffusion coefficient of CO_2, reaction velocity constant, CO_2 concentration in the air for FEMA are decided through literature review. The proposed quantitative evaluation basis in chapter 3 is used to evaluate and predict service life.

In chapter 5, CO_2 emission of concrete considering concrete mix and CO_2 absorption through carbonation during service life for unit volume concrete is calculated quantitatively. And then, CO_2 balance (emission-absorption of CO_2) and $LCCO_2$ is evaluated quantitatively to a real building.

In chapter 6, conclusions of this study are summarized and further study is proposed.

1. Proposal of a quantitative evaluation basis for carbonation depth

a) Carbonation depth is determined. Approximately 60% level of the initial concentration of $Ca(OH)_2$ and the point where the ratio of $CaCO_3$, $Ca(OH)_2$ 1:3 is matched the colored point by indicator.

b) C_0 is the mass loss rate of sample using TG/DTA after 3 months hydration and the value is 1.0% and it is expected to the lowest because the sample is

not carbonated yet. C_{max} is the mass loss rate of sample using TG/DTA when the value does not rise up more in a chamber of 100% CO_2 gas in the air so the sample is expected to be fully carbonated and the value is 27.15%. pH value at that time is 10.6 and this value is expected sample to be fully carbonated experimentally.

c) Proposed quantitative evaluation method considering carbonation degree for carbonation can evaluate even in 1 week carbonation time even though method by indicator cannot evaluate because of uncolored concrete. Carbonation degree with water to cement ratio of 0.45, 0.55, 0.65 is evaluated D_{c45} = 23.3%, D_{c55} = 64.8%, D_{c65} = 82.1% in 26 carbonation weeks at 5% of CO_2 concentration.

2. Prediction of service life to all mixtures of concrete using carbonation degree

a) Hydration model is valid to estimate the amount of $Ca(OH)_2$ after comparing experimental value and predicted value.

b) Predicted value using a point where the concentration of $Ca(OH)_2$ is 60% value shows similar existing result after comparing exiting predicted model.

c) Prediction of service life for carbonation to all mixtures of concrete is possible by the result of FEMA using a hydration model and carbonation degree.

3. Proposing of evaluation method for concrete $LCCO_2$ by carbonation degree

a) In terms of CO_2 reduction, evaluation method of $LCCO_2$ and CO_2 balance for concrete with proposed carbonation can be used for determining the mix proportion of concrete and service life of structure.

This study is a limit that cannot be used as the method for quantitative evaluation of concrete carbonation, because it is based on only the experimental result for water to cement ratio of 0.45, 0.55 and 0.65 with ordinary Portland cement. In future, an additional investigation for the concrete with fly ash and blast furnace slag will be needed.

Contents