Modeling of Environmental Response for Concrete Durability

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Abstract

The most common deterioration cause of concrete structures over the world is chloride ions attacks. Thus, service life modeling of concrete is a crucial issue in civil engineering society. Many studies on the durability of concrete have been accomplished, however, it is not easy to review literatures about environmental analysis. Since the durability of concrete depends on the properties of the surface concrete. micro-climatic condition which influences on surface concrete realistically should be considered.

This study is devoted to analysis the micro-climatic condition of concrete structures, based on the in-situ monitoring of weather in marine environment. The effect of degree of saturation on chloride diffusivity of concrete is also examined. It is expected that the result of this work should be available for the prediction of chloride profile of marine concrete.

키워드 : 염소확산계수, 미세기후조건, 환경해석, 내구성
Keywords : Chloride Diffusivity, Micro-Climatic Condition, Environmental Analysis, Durability

1. INTRODUCTION

Performance based demands for new structures have pushed awareness of durability in the spotlight. In the process environmental actions should be considered carefully because that is decisive for many deterioration processes. The climatic conditions known for a structure are usually available from meterological data. The data defines the regional climate for the structure, undisturbed by the structure itself. Some of researchers used the meterological data directly to consider the environmental response of concrete, however, this is not reasonable because the data is different with real data concrete itself suffered. This is why the emphasis in this study has been put on the environmental actions and response from the concrete[1].

The objective of this study is to explore environmental actions on concrete and the response from the concrete and to define micro-climatic condition and to examine the effect of the micro-climatic condition on chloride penetration in concrete on the long term. Since the influence of the environment on the deterioration depends on deterioration processes, this study shows how to make coupling of micro-climatic condition and chloride penetration of concrete.

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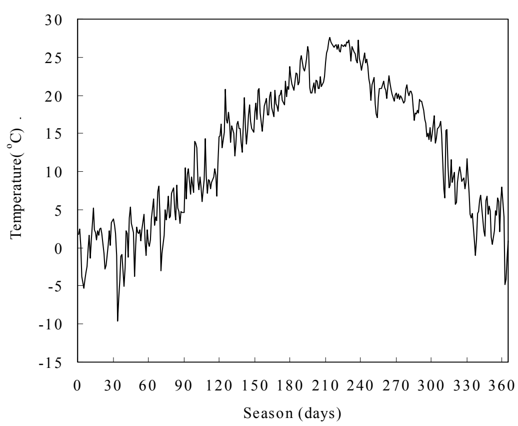
2. MICRO-CLIMATIC CONDITION OF CONCRETE IN KOREA

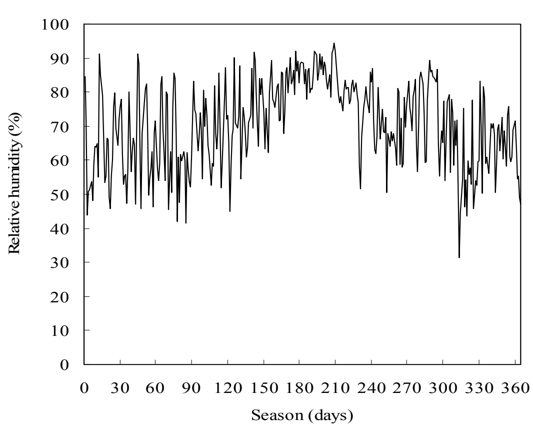
2.1 Climatic Monitoring

Air temperature and relative humidity data for representative places close to the location of the structure are usually available from meteorological institutes. KICM, Korea Institute of Construction Materials, has outdoor exposure testing institute sponsored by Korean Ministry of Knowledge Economy. This institute has automatic weather monitoring system and metrological data such as wind velocity, RH, temperature, sun shine, etc, can be obtained at real time. Fig. 2 shows the results for a year. These were used as input data for computation of micro-climatic condition.

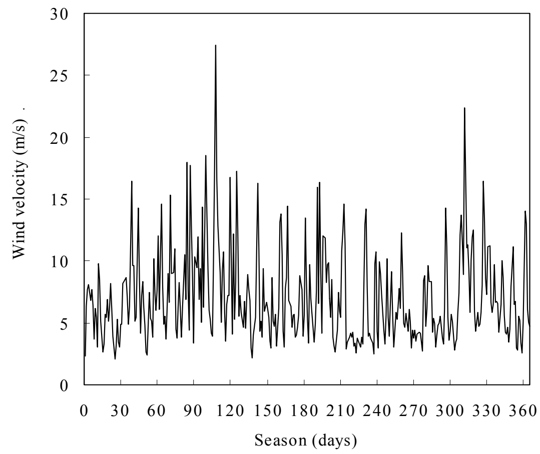
Fig. 1 Monitoring of climatic condition(KICM, Seo-san,Korea)



(a) Temperature



(b) Relative humidity



(c) Wind velocity

Fig. 2 Results of weather monitoring in Seo-san

2.2 Micro-climatic Analysis

Atmospheric condition had been used in service life modeling and the estimation of performance of concrete in most of all researches, although there is a difference between real condition and atmospheric condition of concrete. That is, the temperature (Tatm) and RH (RHatm) of atmosphere are different with these of surface concrete, Tcon, RHcon. The temperature and moisture condition in concrete during the service life should be predicted by solving the energy and mass balance equation.

Since durability of concrete is governed by the properties of surface concrete, it is very important to quantify the interaction between atmosphere condition and surface concrete. In order to simplify the interaction, the concept of equivalent temperature (Eq. 1) and equivalent RH (Eq. 8) are considered in this study. It is possible to use the analogy between the surface temperature and the atmospheric temp., following the concept of equivalent temperature; With the Eq. (2), outdoor radiation temp. can be computed.

$$t_{eq} = \frac{h_c \cdot t_a + h_r \cdot t_r}{h_{cr}} \qquad (1)$$

tr = FFsky · tsky+tsuf(1-FFsky) (2)

$$hc = 6 + 4 \cdot Vew \quad (3)$$

$$hr = 4(tr+273.15)3 \quad (4)$$

where, hc : outdoor convection coefficient,
hr : outdoor radiant transfer coefficient,
FFsky : sky form factor (≒ 0.5),
σ : Stefan-Boltzmann constant (=5.67×10-8 W/m2K4),
tsky : temp. in sky,
tsuf: surface average temp.,

The sky temperature can be expressed approximately as Eq. (5) and the dew point temp., tdp, can be determined by Eq. (6).

$$t_{sky} = t_{atm}\left(0.8 + \frac{t_{dp}}{250}\right)^{0.25} \quad (5)$$

$$t_{dp} = \frac{b}{a - \ln c} \quad (6)$$

If temperature > 0 oC, a and b equal 20.111, and 506.73, respectively. Otherwise, these are 23.077, 5871.99. c means the vapor content in the water and is computed from the definition of RH. by Eq. (7). The radiation is the cause of the fact that temperature of the concrete to be a higher than the atmosphere temperature. This situation induces that R.H at the surface of the concrete would be a bit lower than in the surrounding atmosphere. Assuming constant vapor contents, the surface humidity can be calculated by Eq. (8).

$$c = \frac{R.H \cdot v_{sat}}{100} \quad (7)$$

$$R.H_{eq} = \frac{R.H_{at} \cdot v_{sat}(t_{at})}{v_{sat}(t_{eq})} \quad (8)$$

where, RHat : RH in atmosphere,
vsat: vapour content at saturation in atmosphere.

Fig. 3 shows procedure for computation of equivalent temperature and equivalent RH to define micro-climatic condition.

3. RESULTS AND DISCUSSION

Fig. 4 shows theoretical vapour content in air saturation depending temperature. This was used for calculation of temperature of concrete.

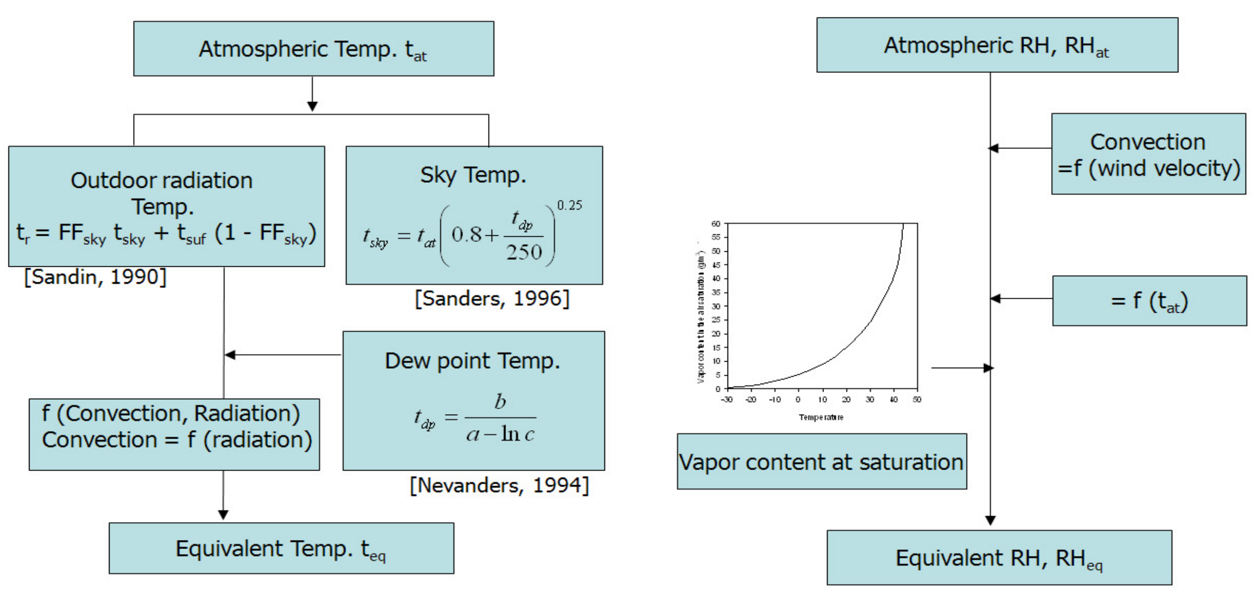


Fig. 3. Outline for computation of micro-climatic condition of concrete2,4~6)

Fig. 5 represents computed result of equivalent temp. Equivalent temp. is always lower than atmosphere temp., however, difference between two temperatures is obvious in winter season.

Fig. 6 shows equivalent RH in concrete. RH at the surface of the concrete is somewhat lower than in the atmosphere. With a concrete surface temperature below the dew point condensation will occur and a certain wetness as a thin water film will be obtained. For durability design analsysis of concrete, some of researchers had used atmosphere temperature and atmosphere RH in which concrete does not suffer. However, equivalent temp. & RH are more reasonable than atmosphere temp. & RH. Meanwhile, it is necessary to examine the effect of weathering condition on durability performance of concrete.

Author1 had developed analytical approach to compute chloride diffusivity of concrete. Chloride diffusivity of concrete can be influenced by a lot of factors such as (a) ionic diffusivity in water, (b) properties of pore size distribution in hardened cement paste, (c) tortuosity of flow, (d) hindrance effect due to narrow pore or mutual crushing of chloride molecules, as shown in Fig. 7. In this model, temperature has influence on viscosity of pore water in cementitious materials and this is a cause of change of the chloride diffusivity of concrete, according to the theory.

Fig. 8 shows schematic diagram for coupling of the micro-climatic analysis with the diffusivity of concrete. Increasing temperature influences on viscosity of water in pore and this can lead to decrease diffusivity in pore solution of concrete. This is why this paper is devoted to examine micro-climatic condition at the surface of concrete.

Fig. 9 shows the computational results of chloride diffusivity of concrete considering constant temperature(20oC), atmosphere temperature and micro-climatic temperature. Although the effect of three types of temperature on chloride diffusivity seems to be same, chloride diffusivity of concrete must be computed accurately. Because the chloride diffusivity of concrete can greatly impact on the service life of concrete structures.

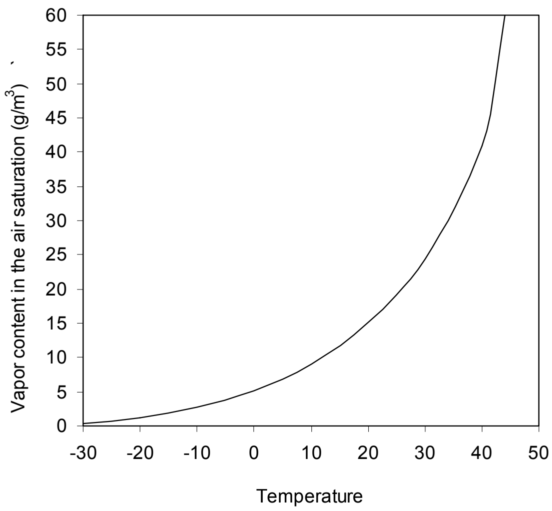


Fig. 4 Vapor content in air saturation

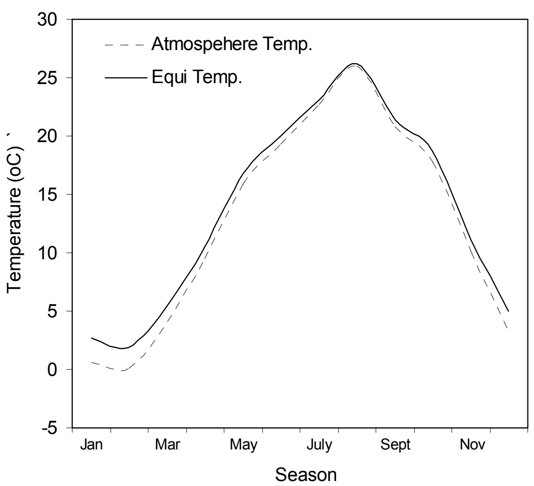


Fig. 5 Equivalent temp. in concrete

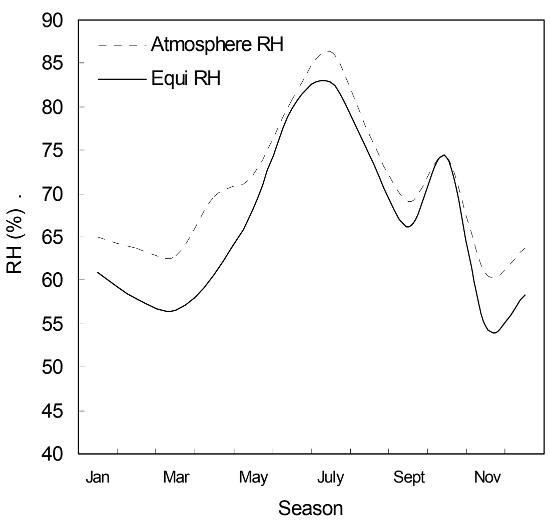


Fig. 6 Equivalent RH in concrete

For future research, it is necessary to consider temperature and RH profile with depth from surface of concrete, as shown in Fig. 10. This should lead coupling of the profile and chloride diffusivity, therefore, the theoretical computation of chloride diffusivity with depth from surface of concrete.

4. CONCLUSIONS

This study presents an approach for micro-climatic condition and coupling with material parameter of marine concrete. The results show that chloride diffusivity of concrete is influenced by micro-climatic environment.

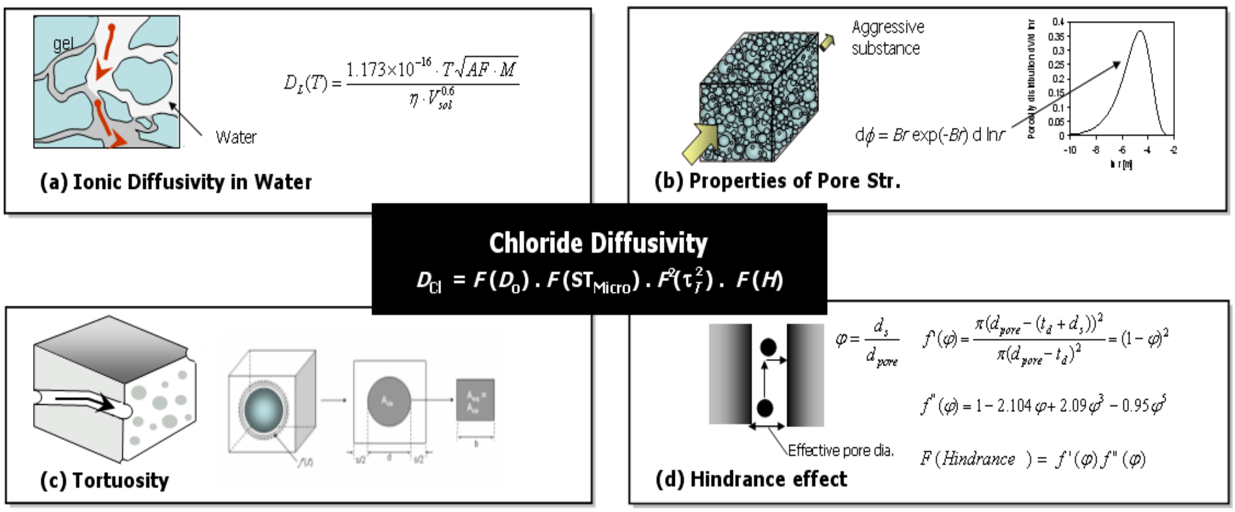


Fig. 7. Formation of Chloride diffusivity to consider various affecting parameters3)

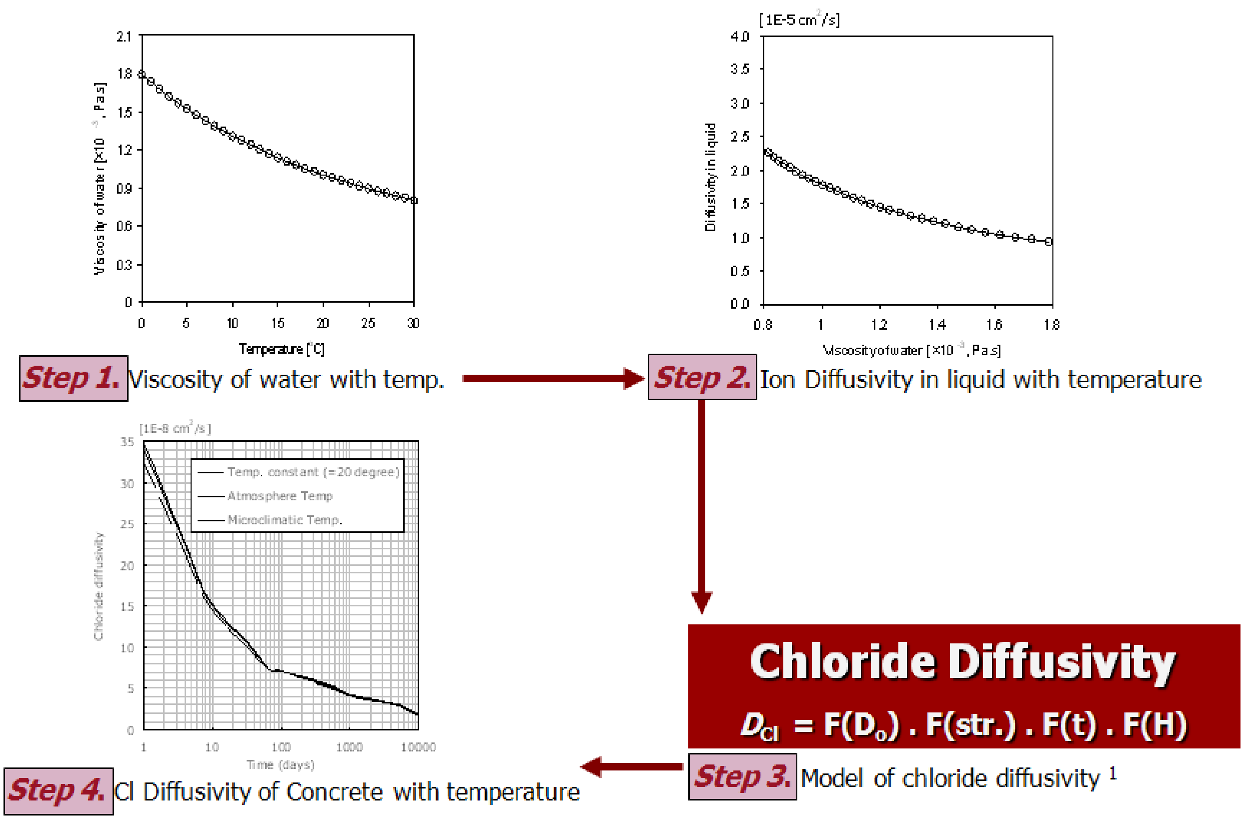


Fig. 8. Strategy for coupling of micro-climatic condition with chloride diffusivity of concrete

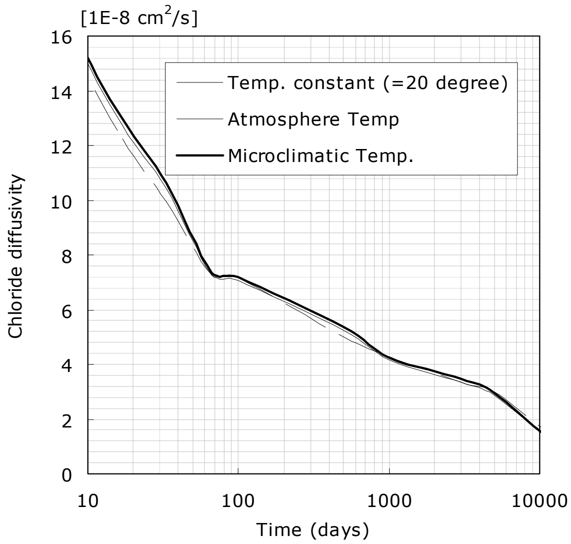


Fig. 9. Effect of temperature on chloride diffusivity of concrete

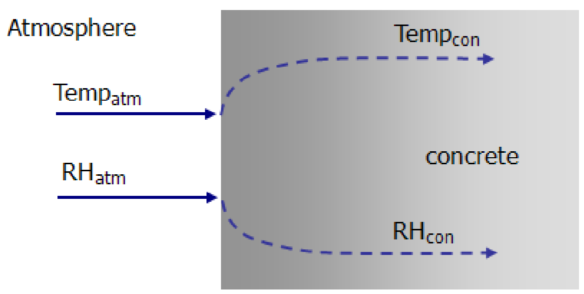


Fig. 10. Micro-climatic condition of concrete

This study can provide a fundamental approach to calculate rational micro-climatic at surface concrete and this should be useful to formulate environmental affecting factors as an input parameters in the durability design systems of marine concrete.

This research is expected as framework to develop environmental model environmental action / response in terms of durability design of concrete. The micro-climatic condition of concrete will be described with variations on an annual basis of temperature and RH.

ACKNOWLEDGEMENTS

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콘크리트의 열화는 현재 전세계적인 관심 분야로서 가장 보편적인 열화원인은 염해이다. 이를 고려한 내구수명 예측기법의 개발은 토목건설 기술에 매우 중요한 부분을 차지하고 있으나, 대부분의 기존의 연구는 수명예측에 대한 기법에 집중되어 왔을 뿐, 콘크리트 표면의 미세 기후조건을 고려한 환경 분석은 매우 드문 실정이다. 그러나 콘크리트의 내구성은 표면의 특성에 의해 지배되므로, 실질적으로 표면상태에 대응한 미세 기후조건을 연구하여 환경대응 인자로 정립할 필요가 있다.

본 연구는 현장 기후조건을 계측하여 콘크리트의 미세기후조건을 해석할 수 있는 방법을 제안하였다. 이 결과는 염소이온 확산계수와 같은 재료 매개변수에 반영하여 더욱 정밀한 수치 해를 얻는데 이용되었다. 본 연구는 콘크리트의 내구성 설계기법을 개발하기 위하여, 환경인자에 대응한 매개변수를 도출하는데 이용될 수 있을 것으로 기대된다.