論 文 の 内 容 の 要 旨

論文題目　A Comprehensive Numerical System for Predicting Airborne Chloride Generation and its Ingression into Concrete Under Actual Environmental Conditions
(実環境下における飛来塩分発生およびコンクリート内部への浸透を予測する包括的数値解析システム)

氏　　名　　ワッタナポーンプロム　ルンラウィー

In a marine environment, deterioration of reinforced concrete structures is caused by airborne chloride attack and thereby many infrastructures used in the coastal area sometimes require repair or reconstruction due to the corrosion of reinforcing steel bars. The recent JSCE standard specification presents a simple method for durability design of marine environment structure. However, the proposed method has been formulated based on the limited number of measured data and it needs to be improved for reasonable durability design. Therefore, a reliable prediction model to calculate airborne chloride penetration into concrete structures is necessary to evaluate the service life of concrete structures and to realize rational maintenance.

However, there are some difficulties in predicting the chloride ingression into concrete structure due to airborne chloride, since chloride concentration on the concrete surface depends on the amount of airborne chloride supply, which varies due to wind direction, wind speed, wave height, obstacles, distance from the seashore, etc. In addition, when a structure is exposed to airborne chloride environment, chloride and water ingression do not occur uniformly on the concrete surface. Consequently, the chloride ingress model for the direct exposure case, such as submerged condition or cyclic wetting and drying condition, cannot be used to predict chloride penetration in case of airborne chloride attack. Furthermore, under actual environmental conditions, the chloride concentration on the concrete surface can be affected by rainfall, which means pure water can wash chloride out from the concrete surface and chloride inside the structure gradually diffuses out. As a result, the reduction of the total amount of chloride in the

concrete structure takes place. Hence, a new model to predict chloride ingress into concrete structure under complex airborne chloride environment is needed.

Against the above background, this study proposed a comprehensive system for calculating the amount of chloride generation, transportation, and ingression. The system is consists of three numerical models, which are airborne chloride generation and transportation model, moisture and chloride flux model at the boundary surface and chloride ion transport model in cementitious materials. By connecting each calculation model together, the proposed framework will be able to determine the amount of chloride ingression under the actual environmental condition without recorded airborne chloride data. Firstly, the amount of airborne chloride at the specified position can be calculated by using the airborne chloride generation and transportation model. After the airborne chloride amount has been calculated, the data will be given as the input for the airborne chloride surface flux model. Each model in the comprehensive system has been verified by the experiment and/or onsite measurement data to confirm the validity of the model.

The moisture and chloride flux model at the surface has been formulated as a time-dependent computational model for predicting the amount of airborne chloride ingress into concrete under the actual environmental conditions. The proposed model calculates the amount of chloride penetration by considering the amount of advection and diffusion of airborne chloride on the concrete surface. To compute the amount of airborne chloride, the proportion of dry and wet sections on the concrete surface is assumed, and to ensure accurate prediction of chloride penetration into concrete structures under actual environment conditions, the washout effect of rainfall is also taken into account in the calculation.

To verify the moisture and chloride surface flux model, the experimental series are conducted under controlled conditions in a laboratory. From the verification, the proposed model can predict the chloride ingression under airborne chloride condition, water ingression and washout chloride amount under specified condition. Moreover, the onsite measurement data were also used to verify airborne chloride ingression under actual environmental condition. From the verification, it is shown that the proposed model can appropriately simulate the chloride penetration and washout effect of mortar specimen under actual environment conditions. In some cases, the analysis gives the dissimilar value compared with the exposure testing result. This may be due to the limitation of the meteorological data, and/or the fact that

the assumptions used in the proposed model do not correspond to the actual exposure conditions.

The airborne chloride generation and transportation model can be used to predict the amount of airborne chloride at the specified position by input the data of breaking wave height, wind direction, wind speed, obstacles, distance from the coastline etc. The calculated airborne chloride data from the airborne chloride generation and transportation model have been verified by onsite measurement data. From the verification, the chloride generation and transportation model can predict the amount of airborne chloride at each location under different exposure condition.

Finally, after the verifications of each model, the overall system also has been verified by onsite measurement data at Okawa Bridge. The verification results showed that the proposed system can calculate the total chloride amount when the structure subjected to the rainfall (flange position). However, the analysis results at web position are not well predicted. The reason may be due to the limitation of the proposed system which cannot calculate the chloride penetration in unsaturated concrete. Thus, the future modification of the chloride ion transportation should be considered.