V-18 Actual Environmental Effects on Airborne Chlorides Transportation

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1. Introduction

The prediction of chloride concentration in concrete under actual environmental conditions is indispensable for identifying the life-span period of a structure. The plenty of environmental parameters relates with the chloride attack to concrete structures. The quantitative effects of environmental conditions on chloride attack to a structure are used to classify the level of severity. In 1983, Japan Roads Association [2] organized to monitor the structural conditions on soundness, chloride concentration in concrete and cracking provision. The consideration of time history of overall investigated structures can elucidate the severity of a region. The summarization of the severity was shown in **Table 1.** The amount of airborne chlorides available in the atmosphere at a certain distance is applicable to explain the different harshness on damage in concrete structures. Thus, it is necessary to know the amount of airborne chlorides in various locations all over Japan for using as complementary of chloride transport to concrete structures. PWRI 1985 [1], the airborne chlorides in various distances from seashore were investigated around Japan. The investigated data was plotted and illustrated the severe zones in all locations around Japan. The presentation of the investigated results is able to explain the level of severity, as well. The simulation of available airborne chlorides was done in the function of actual wind speed, and the relationship was proposed as an empirical formula.

Table 1: Classification of severity of chloride attack

Zone	Locations	Distance from seashore	SEVERITY
A	Okinawa	Up to 100m from seashore	I
		Other distances	II
B	Japan Sea Coastline	Up to 100m from seashore	I
		100-200 m	II
		200-300 m	III
C	Others	Splash zone	I
		Up to 100m from seashore	II
		100-200 m	III

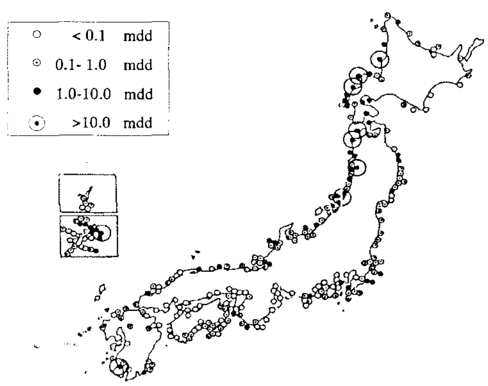

Fig.1 The investigation of airborne chlorides by PWRI

2. Airborne chlorides and environmental relationship

Many literatures were published about chloride attack in concrete in both macro and micro simulations. Japan Metropolitan Electrical Research Center [3] prematurely organized to observe some factors of chloride attack in concrete structures. The level of severe chloride attack was classified as the available airborne chlorides in the atmosphere. Thus the measurement of airborne chlorides in the atmosphere related with environmental factors was examined. In 1984-1985, PWRI started the measurement of accumulative airborne chlorides in monthly for whole year. Later PWRI 1993 [4], the airborne chlorides transportation was proposed as in wind speed and wind ratio of landward directions. In the regression analysis of a numbers of the experimental results, the average airborne chlorides was proposed by classifying into two quantitative conditions without categorization of distance from seashore expressed as,

- Low-scale of airborne chlorides

$$C_{air} = 0.0515.r.U^{2.27} \tag{1}$$

- Large-scale of airborne chlorides

$$C_{air} = 0.0150.r.U^{3.29} \tag{2}$$

C_{air} is daily airborne chlorides (mg/dm^{2}/day), U is wind speed (m/s), r is the ratio of wind in landward direction

In this regression analysis, the low-scale and large scale of airborne chloride calculated by **Eq.1&2** has the regression value at 0.488 and 0.671, respectively. Without taking distance into account, the variety of data makes the low accuracy of the proposed empirical formula. The accumulative airborne chlorides in the atmosphere should be collaborated among wind speed, ratio of wind direction, and distance from seashore. Thus, the distance far from sea is thought as the reduction of available airborne chlorides in the atmosphere.

Another relationship of airborne chlorides at a distance from seashore was proposed later by PWRI, 1993 [4] and Japan Roads Association, 1983 [2]. Japan Roads Association, 1983 proposed an empirical formula related with the distance from seashore by separating into three zones as illustrated in **Table 1.** The relationship between distance from seashore and average airborne chlorides is shown below,

Keywords; Actual environments, accumulative airborne chlorides, airborne chlorides transport and chlorides attack

$$C_{air,d} = C_{o,air}.e^{-1.55\sqrt{\frac{l}{1000}}} \quad (3)$$

$C_{air,d}$ is airborne chlorides in a distance (mdd) and $C_{o,air}$ is daily average airborne chlorides at seashore (mdd)

Next, PWRI, 1993 used investigated data of large-scale airborne chlorides investigated in 1985 for obtaining the distance relationship. The airborne chlorides relationship was offered with the power function with distance from seashore. In **Eq.3**, the amount of airborne chlorides at 1km represents the relationship of airborne chlorides due to the fittest relationship in regression analysis.

$$C_{air,d} = C_{air,1} * (0.001 * l)^{-0.6} \quad (4)$$

$C_{air,d}$ is airborne chlorides in a distance (mg/dm2/day), $C_{air,1}$ is airborne chlorides at 1 km from seashore ($mg/dm^2/day$) and l is distance from seashore (m)

3. Relationship between airborne chlorides and surface chlorides on surface of concrete

Referred to the investigation by PWRI [1], the investigation was done in two sections of airborne chlorides and the accumulative chloride concentration on surface of concrete (kg/m^3). The second part of the investigation was to evaluate the relationship between airborne chloride and chloride concentration at surface of concrete. Exposure test of concrete blocks with w/c of 0.39 & 0.58 were also done for the survey of chloride concentration. The concrete blocks were located at the same location of the investigation of airborne chlorides. The amount of airborne chloride accumulated at surface of concrete penetrated through concrete during exposure time. The result of chloride concentration in concrete was measured in 2 cm interval, and the surface chloride concentration was predicted. Overall predicted data of surface chloride concentration and the average airborne chlorides was plotted as shown in **Fig.3**.

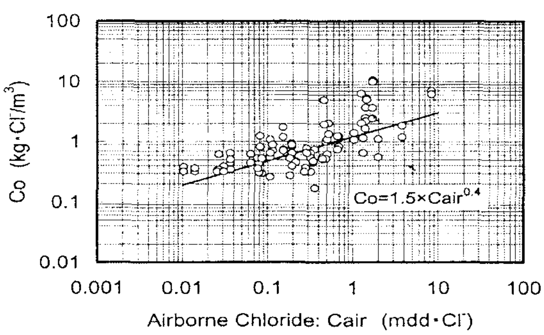

Fig.3 Relationship between airborne chlorides and chloride at surface of concrete [5]

The regression analysis was used in order to obtain their relationship, which was propose as

$$C_o = 1.5 \text{ x } (C_{air})^{0.4} \quad (5)$$

C_o is the chloride concentration at surface of concrete (kg/m^3)

The log-scale plotted in **Fig.3** shows very large dispersion up to 10 times disparity at a constant value of airborne chlorides. The R value of the proposed equation is less than 0.7, and it seems very difficult to simulate the relationship between airborne chlorides and chloride concentration in concrete.

The last parametric study is the raining effect on accumulative airborne chlorides. During raining, the airborne chlorides transporting with windblown are precipitated to the ground. Hence, the accumulative airborne chlorides remain constantly during raining period. It is considered that raining does not play an important role to the airborne chlorides transportation, but it is the most important factor to the removal of the accumulative chloride concentration on the surface of concrete. However, the investigation on effect of rain to dissolve chloride at surface of concrete has not been published yet.

4. Conclusions

This formula for calculating airborne chlorides in the atmosphere was functioned as wind speed and the distance from seashore. The empirical formula to compute the amount of airborne chlorides was proposed in order to understand quantitative effect of actual environmental conditions. However, the equations acquired from the regression analysis were not sufficiently accurate to understand the real effect of environmental conditions on the airborne chlorides transport in the atmosphere and on the surface of concrete. The empirical formulas were the variety of performances due to plenty sets of investigated data. The systematic calculations on airborne chlorides transport and their accumulation on surface of concrete including the penetration are necessary for future study on chloride attack to concrete structures.

5. References

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