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

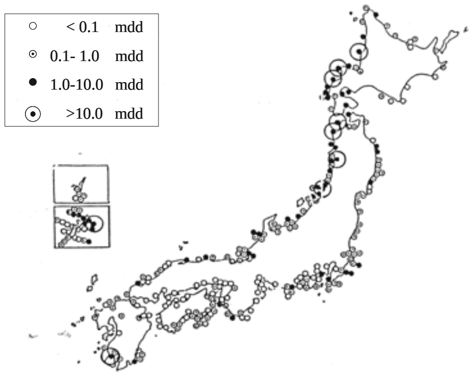


Fig.1 The investigation of airborne chlorides by PWRI

2. Literatures reviews

Many literatures were published about chloride attack in concrete in both macro and micro simulations. Japan Metropolitan Electrical Research Center [**3, 4**] 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. 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 as,

- Low-scale of airborne chlorides

$$C_{air} = 0.0515.r.U^{2.27} \qquad \textbf{(1)}$$

- Large-scale of airborne chlorides

$$C_{air} = 0.0150.r.U^{3.29} \qquad \textbf{(2)}$$

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

Another relationship of airborne chloride at a distance from seashore was proposed later by PWRI, 1985 [**1**]. The airborne chlorides relationship was offered with the power function with distance from seashore.

$$C_{air,d} = C_{air,1} * (0.001*X)^{-0.6} \qquad \textbf{(3)}$$

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

3. Quantitative simulation of environmental effects on airborne chlorides transport

Referred to the computational model on airborne chlorides formation and transportation [**5**], the airborne chloride is generally formed by wave breaking along shoreline. The horizontal wind and residual wave energy after breaking transport airborne chloride upward at a certain height. Afterward, airborne chloride is transported into land by wind speed, and dropped with gravitational motion described in **Fig.2**.

Keywords; actual environments, airborne chloride, air borne chloride transport and airborne chloride formation

Following this model, an empirical formula is expressed as follows;

$$C_{air,hr} = 0.35.U^3 * (X+10)^{-0.5} * r_{wind} \qquad \textbf{(3)}$$

$C_{air,hr}$ is the hourly airborne chlorides ($mg/dm^2/hr$);
r_{wind} is 1.0 in case of the efficient wind direction
0 in case of non-efficient wind direction
The results of calculation in **Eq.4** are expressed in **Fig.2** by varying wind speeds of 4, 8 and 12 m/s, respectively.

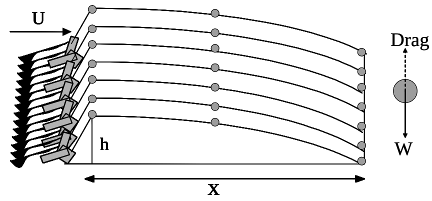


Fig.2 The simple model on airborne chloride formation and transportation

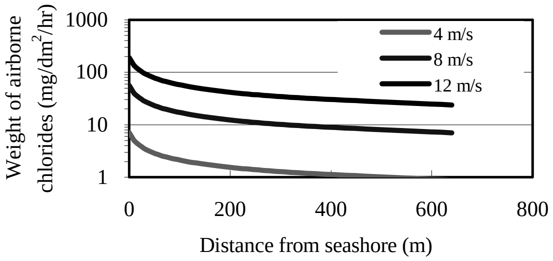
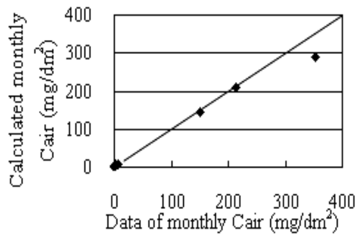


Fig.3 The amount of airborne chlorides in hourly related with distance from seashore and wind speed.



Data Notes	X(m)	Data	Cal.
Shikoku-May	80	7.5	6.0
Hokaaido-Dec	20	213.2	210.0
Shikoku-Aug	200	0.7	2.0
Shikoku-Apr	400	0.4	1.2
Shikoku-Nov	50	0.4	1.2
Kochi-Oct	30	2.1	4.0
Kochi-Oct	100	0.6	1.8
Kochi-Oct	300	0.3	1.0
Okinawa-Sep	50	352.8	288.3
Chukoku-Dec	50	150	144.0

Fig.4 Verification by monthly accumulative airborne chlorides using the analysis of actual environments in hourly data

Considering effect of wind directions on airborne chlorides transportation, firstly the effective wind direction defines as wind in the perpendicular to the structure surface as the shortest transporting distance. The common efficient wind directions (r_{wind}) are in the angles of ±67.5°, but it might be less due to the particular coastal panorama. The effect of the efficient wind directions is considered as the longer distance of transportation as in **Eq.4**. In this case, the value of X' in each hourly wind speed is substituted into **Eq.3**. Afterward, the calculation of accumulative airborne chlorides in duration of time is succeeded.

$$X' = X / \cos \varphi \qquad \textbf{(4)}$$

X is distance from seashore in effective wind, X' is distance from seashore in efficient wind directions and φ is deviated angle from effective wind direction

The last parametric study is the raining effect on accumulative airborne chlorides. The method to measured accumulative airborne chlorides is recommended as in JIS Z2381 using steel plate in the dimensions of 10x10 cm under roof. 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 noted 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.

Finally, the investigated results of accumulative airborne chlorides in a month all around Japan are used for comparing the results calculated from proposed equation illustrated in **Fig.4**. As the results, the proposed equation gives precise estimation in a certain level; however it underestimates in the very severe location, especially in the storm duration.

4. Conclusions

The environmental factors of wind speed, wind directions, and distance from seashore are systematically regarded as the amount of airborne chlorides transportation. An empirical equation is proposed by integrating all environmental factors related with airborne chloride transport together in a formula. This formula is for estimating the amount airborne chlorides in the atmosphere in any locations and environments. However, the computation value underestimates an experimental result in the region where had a heavy storm during measuring period.

5. References

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