Study on Similarity Criterion of Chloride Diffusion Coefficient under Continual Immersion of Marine Prestressed Concrete Structures

XU Xianzheng

Faculty of civil engineering and mechanics, Jiangsu University, P.R.China, 212013

Abstract-Based on the similarity theory, the similarity criterion and criterion equation are derived from the analysis of chloride ion in concrete. The experiment is designed and implemented, and the criterion is obtained by fitting the experimental data. It is proved that it has good applicability.

Key words - *dimension theory, similarity criterion, criterion equation, simulation test*

Ⅰ. Introduction

The harshness and complexity of marine environment is an important factor affecting the durability of marine prestressed concrete structure. Especially, the durability of prestressed concrete structure in marine environment is the most serious, and the researchers are from laboratory tests and engineering field test of two aspects of chloride ion diffusion analysis. In laboratory tests, the diffusion of chloride ions in concrete can be controlled by increasing the concentration of the attack solution, increasing the test temperature or accelerating the current. The change of the parameters can not only control the variation of the parameters. The law of the parameters is not the same as the actual ones. Therefore, The field test structure is in the actual erosion environment, through a long time to track the record to ensure that the most consistent with the actual spread of the law, but the test cycle is too long, and the cost is too high.

The diffusion process of chloride ions in concrete is generally considered to be in accordance with Fick's second law, and it is assumed that the chloride ion diffusion coefficient is constant, and in fact the diffusion coefficient varies with time and environment. The introduction of similarity theory is a new approach to the durability of prestressed concrete structures. The similarity between the two is simulated by simulating the field structure and the durability of the field structure is estimated. In this paper, the similarity criterion of chloride diffusion coefficient of continuous prestressed concrete structure is deduced, which reduces the number of simulation test parameters and accumulates the experience of similarity theory in durability.

Ⅱ. Similar to the Derivation of Criteria

For the complex phenomenon of the complex phenomenon is not yet clear mechanism is to derive the similarity of the most basic and practical method, the method only need to know the physical quantity contained in the phenomenon can be.

For the given concrete material, the ratio of curing, curing and other conditions to determine the chloride diffusion coefficient D is mainly affected by the structural or mechanical action and the role of the role of the coupling effect[1], time t, transmission distance x, ambient

temperature T (Continuous infiltration does not take into account the environmental relative humidity), the internal structure of the stress f, etc., they can use the general function of the relationship to express $D=h\,(\,t\,,\,x\,,\,T\,,\,f\,)$

Including the basic dimension strength F, length dimension L, time dimension Θ, the dimension matrix[2] of these five variables is

	D	t	T	x	f
F	0	0	1	0	1
L	2	0	1	1	-2
Θ	-1	1	0	0	0

The rank of the dimension matrix is 3, then the similarity criterion is 5-3 = 2. Let a_1,a_2,a_3,a_4,a_5 represent the exponent of parameter D,t,T,x,F, respectively

	a_1	a_2	a_3	a_4	a_5
	D	t	T	x	f
F	0	0	1	0	1
L	2	0	1	1	-2
Θ	-1	1	0	0	0

Thus, three linear homogeneous algebraic equations are obtained

$a_3+a_5=0$, $2a_1+a_3+a_4-2a_5=0$, $-a_1+a_2=0$

In the above equation, the three equations contain five unknowns, assuming that a_2, a_5 are known

When $a_2=1,a_5=0$, we can get $a_1=1,a_3=0,a_4=-2$;
When $a_2=0,a_5=1$, we can get $a_1=0,a_3=1,a_4=3$.

These solutions can be expressed in the form of a π matrix, as follows

	a_1	a_2	a_3	a_4	a_5
	D	t	T	x	f
π_1	1	1	0	-2	0
π_2	0	0	-1	3	1

In the π matrix, two similarity criteria can be established according to the exponent of each dimension corresponding parameter

$$\pi_1 = \frac{Dt}{x^2}, \pi_2 = \frac{fx^3}{T} \tag{1}$$

Through transformation

$$\pi_2' = \pi_2^2 \pi_1^3 = \frac{f^2 D^3 t^3}{T^2} \tag{2}$$

The addition or absence of the dimensionless quantity in the dimension analysis does not affect the derivation of similarity criteria. However, the concentration of chloride ions in the process of chloride ion diffusion is a critical parameter, so the similarity criterion[3]

$$\pi_3 = \frac{c_{rt}}{c_{st}} \tag{3}$$

The c_{rt} is the chloride ion concentration (%) at time t from the concrete surface; c_{st} is the chloride ion concentration (%) of the concrete surface at time t.

The similarity criterion is

$$H\,(\,\pi_1\,,\,\pi_2'\,,\,\pi_3\,)=0 \tag{4}$$

III． Test Validation

A ． Specimen design

The experimental design of the concrete specimen in the long-term soaking in the chloride salt solution to verify the durability of the parameters of the criteria of the relationship. According to the civil engineering test standard, the specimen material composition is shown in Table I.

III.Table I Specimen Material Ratio

| power level	cement kg/m^3	water kg/m^3	sand kg/m^3	stone kg/m^3	Water reducing agent kg/m^3	Water-cement ratio
C40	500	210	750	1250	1.50	0.42

The size of the specimen is $100 \times 100 \times 400$ (mm) see Figure 1 (a), the loading level is divided into 0.1 f_c;0.2 f_c;0.3 f_c three grades of compressive stress specimen. The specimen is

set to a diameter of 20mm round hole, both ends of the steel plate (plate style and size shown in Figure 1 (b)), pouring molding, the standard conservation after 28 days, until the concrete reaches the design strength, insert ΦT18 Stress rebar, tensioned steel to make the specimen pressure, loading diagram shown in Figure 1 (c). On the specimen metal components to do anti-rust measures, and the internal edge of the grouting to the end of the glass seal in the form of sealing.
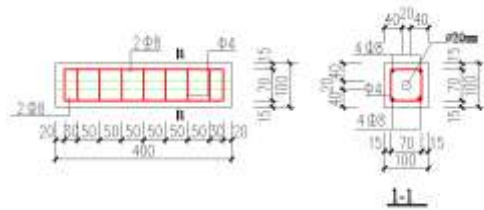
（a）Test component reinforcement(mm)
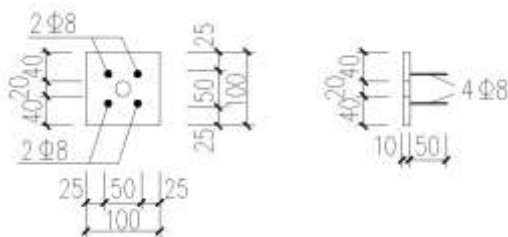
（b）Design of steel plate(mm)
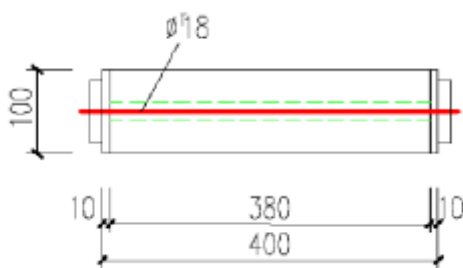
（c）Sketch of test component loading(mm)

Fig1 Specimen construction and dimension drawing

Set the test temperature of 25 ℃, increase the concentration of chloride solution to the chloride ion concentration of seawater [seawater chemical resources utilization technology] about twice to accelerate the erosion, take the whole 5% NaCl solution soak to accelerate erosion.

The samples were periodically tested for their chloride ion erosion. The powder was drilled with the impact drill. The powder was well ground and passed through a 0.63mm sieve. Then, 10 ml of distilled water was added to the powder, and the content of chloride ions was measured by RCT after full immersion[4]. The use of epoxy resin on the drilling of powder after the specimen hole to block, to ensure the reliability and continuity of follow-up test.

B. Test data processing

After analyzing the data obtained by the experiment, π1, π2 and π3 are regarded as a whole, and the data is fitted with MATLAB data fitting toolbox to get the data

$$\pi_1 = 3.48 \cdot 10^{-10} \cdot \pi_2'^{\,0.7508} \cdot (lg\pi_3)^{0.00939} \quad (5)$$

which is

$$\frac{Dt}{x_2} = 3.48 \cdot 10^{-10} \cdot \left(\frac{f^2 D^3 t^3}{T^2}\right)^{0.7508} \left(lg\frac{c_{rt}}{c_{st}}\right)^{0.00939} \quad (6)$$

It is proved that the chloride diffusion coefficient D calculated by this formula is on the same order of magnitude as that of the existing formulas, and the formula expresses the diffusion coefficient of chlorine ions with the temperature T, the stress f and the inside distance of the concrete The relationship of surface distance x shows its progress.

IV. Engineering Applications

According to the problem of chlorine salt erosion durability in Lianyungang port, the beryllium content of the structure was measured and the powder was tested in November 2016, and the environmental conditions were investigated. The chloride ion content of the powder is the same as that of the laboratory tests. Select a low water level area, take three detection points, the chloride ion content detection shown in Figure 2.
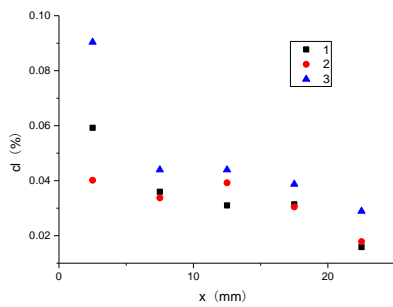
Fig2 Determination of chloride ion in a low water level area

The chloride ion diffusion coefficient

$$D = 1.32 \cdot 10^{-6}$$

is obtained by the criterion equation, which is on the same order of magnitude as that obtained from other literatures.

V.Conclusion

1 In this paper, based on the similarity theory, the criterion of the diffusion process of chloride ions in concrete is determined by dimension analysis:

$$\pi_1 = \frac{Dt}{x^2} \quad \pi_2' = \frac{f^2 D^3 t^3}{T^2}, \pi_3 = \frac{c_{rt}}{c_{st}}$$

2 The laboratory simulation test was designed and simulated. The laboratory tests process was used to simulate the erosion process of the field engineering. The period of the durability test was reduced and the cost was reduced, and the laboratory tests structure type and environmental conditions were controllable.

3 through the test data processing fitting, the chloride ion erosion of the criterion equation:

$$\frac{Dt}{x_2} = 3.48 \cdot 10^{-10} \cdot \left(\frac{f^2 D^3 t^3}{T^2} \right)^{0.7508} \left(lg \frac{c_{rt}}{c_{st}} \right)^{0.00939}$$

And the applicability of the equation is good.

References

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