

Experimental research on chloride threshold level at low temperature: Part2 discussion

Sijia Chen^{1, a}, Xiaobing Song^{1, b} and Xila Liu^{1, c}

¹Shanghai Jiao Tong University, Shanghai 200240, China.

^acsj@163.com, ^bsongxb2014@163.com(corresponding author), ^cliuxila@163.com

Keywords: Chloride threshold level, low temperature, steel corrosion, experimental research.

Abstract. From Part 1, the experimental data of chloride threshold level (CTL) are obtained. With the experimental data, the mechanism of influence of temperature, pitting potential, w/c ratio and air-entraining agent on CTL are discussed in this paper. Lower temperature causes higher CTL by reduce the rate of chemistry reaction. As pitting potential increasing, the CTL will decrease approximately linearly. W/c ratio and air-entraining can lead to higher porosity and weaken the alkaline environment, so as to reduce the CTL.

Introduction

Chloride threshold level(CTL) is one of the key parameters needed for service life prediction of concrete structures[1]. CTL depends on numerous factors[2], on which there are many research papers have been studied[3-7]. However, there are still some limitations of these researches. Most measurements of CTL were performed using a synthetic concrete solution[2], while only a few measurements were performed in mortar specimens[8-10]. Meanwhile, CTL at room temperature was more popular in research than at low temperature. However, assessment of the CTL at low temperature is a key element in predicting the service life of structures in cold regions exposed to chlorides.

From Part 1, the experimental data of CTL at room and low temperature are obtained. With the results, the influence factors of CTL are discussed in this paper. Also, with the combination of other scholars' research, the relationship between CTL and temperature (from -20 °C to 50 °C) is researched.

Results and discussion

Influence of temperature on CTL. Fig. 1 shows the free chloride threshold level for different concrete and different pitting potential. From the figures, it's apparent that CTL at -20 °C is higher than CTL at room temperature under the same condition. When the pitting potential is low, the CTL at -20 °C is approximately 30% higher than at room temperature..

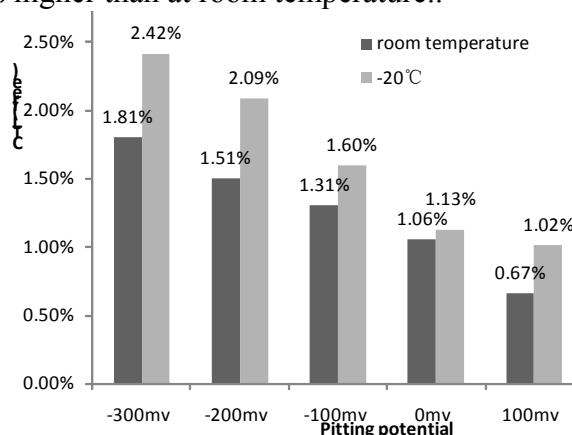


Fig. 1 Free chloride threshold level for specimens with w/c ratio 0.47

Influence of low temperature on CTL is caused by some aspects. Firstly, temperature is an

important factor which can directly affect chemical reaction. Steel corrosion is also an chemical reaction process, so the low temperature can reduce the rate of chemical reaction, which means that it need more chloride to initiate the corrosion under the same condition. Secondly, as temperature decreasing, the hydroxyl ions (OH^-), which protecting steel not to corrosion, in concrete pore solution is increasing. So, more chloride is needed for depassivation.

Meanwhile, as temperature in concrete below 0°C , the pore solution partially frozen, and this leads to increasing of chloride concentration in the pore solution not iced. This phenomenon can reduce the CTL. However, from the experiment, it's known that this phenomenon is not apparent enough to reduce the CTL.

Influence of pitting potential on CTL. Fig. 2 shows the relationship between CTL and pitting potential. From the figures, it's apparent that CTL decreases approximately linearly with pitting potential increasing.

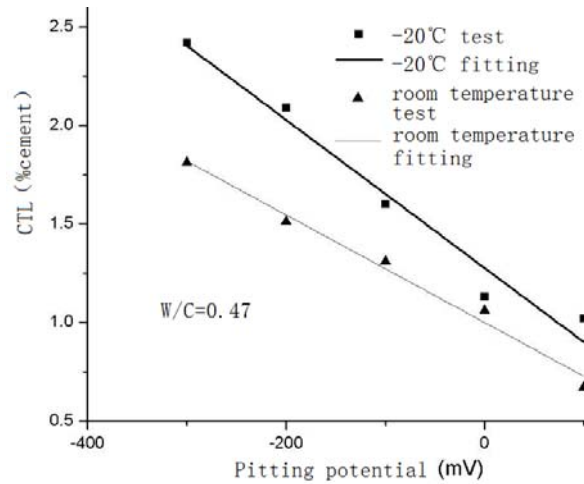


Fig. 2 Relationship between free chloride concentration and pitting potential when w/c ratio is 0.47

Now the influence of pitting potential on CTL will be discussed as follows. Steel depassivation is the process of passive film destroyed by the circumstance changing. In this process, the steel potential is the main factor. Steel potential can influence the stability of the passive film, while steel potential increasing the passive film becomes more and more unstable.

Influence of w/c ratio on CTL. Fig. 3 shows the relationship between CTL and w/c ratio. From the figures, it's apparent that CTL decreases with w/c ratio increasing.

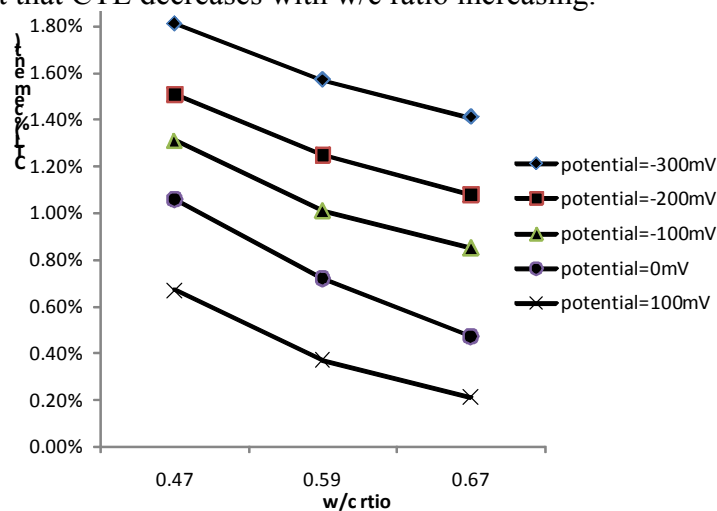


Fig. 3 Relationship between free chloride concentration and w/c ratio at normal temperature

The mechanism of w/c ratio influencing the CTL is to be discussed. From literature, it's known that pH value increases as w/c ratio decreasing. Alkaline environment can insure the stability of the passive film. So, as w/c ratio decreasing, the alkaline environment become better so that the stability of the passive film can be insured, which leads to that higher CTL should be needed to steel depassivation.

Meanwhile, as w/c ratio increasing, porosity of concrete will increase and oxygen become more easily to penetrate to steel surface, which can change the cathodic polarization curve and make the corrosion potential become higher. As corrosion potential increasing, the depassivation become more easily, so the CTL will be lower.

Influence of air-entraining agent on CTL. Air-entraining agent is a common admixture in concrete especially in frost-resistant concrete, which can improve the frost resistance apparently. However, air-entraining agent also can reduce the compactness of concrete, which make more pores exit on the interface between concrete and steel. Consequently, it will increase the risk of corrosion. Fig. 4 shows the difference between CTL in air-entrained and non-air-entrained concrete.

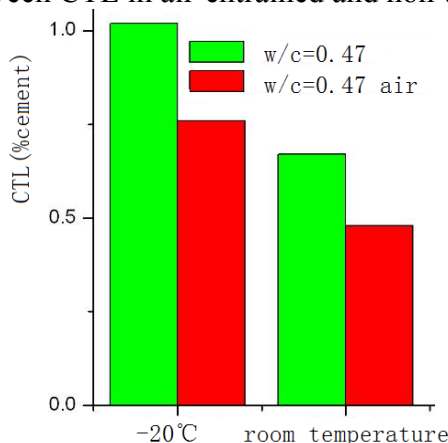


Fig. 4 Chloride threshold comparison of non-air-entrained concrete and air-entrained concrete

The mechanism of influence of air-entraining agent on CTL will be discussed as follows. Firstly, pores on the interface between steel and concrete will reduce the accumulation of hydration product, so as to weaken the alkaline environment[11]. It will lead to steel depassivation easily. Secondly, porosity of concrete will increase with air entrained and oxygen become more easily to penetrate to steel surface, which can change the cathodic polarization curve and make the corrosion potential become higher. As corrosion potential increasing, the depassivation become more easily, so the CTL will be lower

Conclusion

Based on the electrochemistry theory, the CTL under -20 °C and room temperature are experimentally investigated. In this paper, the constant potential controlled and macrocell current measured to determine the corrosion initiation. With the experimental data, the mechanism of influence of temperature, pitting potential, w/c ratio and air-entraining agent on CTL are discussed. Lower temperature causes higher CTL by reduce the rate of chemistry reaction. As pitting potential increasing, the CTL will decrease approximately linearly. W/c ratio and air-entraining can lead to higher porosity and weaken the alkaline environment, so as to reduce the CTL.

References

- [1] Shamsad Ahmad, Reinforcement corrosion in concrete structures, its monitoring and service life prediction--a review, *Cem. Concr. Compos.* 25(2003)459-471.
- [2] C.Alonso, Chloride threshold dependence of pitting potential of reinforcements, *Electrochim. Acta.* 47(2002)3469-3481.
- [3] N.R.Buenfeld G.K.Glass, The presentation of the chloride threshold level for corrosion of steel in concrete, *Corrosion Science.* 39(1997)1001-1013.
- [4] C.Alonso, C.Andrade, M.Castellote, et al., Chloride threshold values to depassivate reinforcing bars embedded in a standardized OPC mortar, *cement and Concrete Research.* 30(2000)1047-1055.

- [5] E.C.F. Standardization. EN 206-1, Concrete - Part 1. Specification, performance, production and conformity[S]. 2001.
- [6] American Concrete Institute. ACI Committee 201, Guide to durable concrete, annual of concrete practice Part 1[S]. Detroit USA: 1994.
- [7] P. Pedferri, L. Bertolini, Durability of Reinforced concrete, Milan, Italia: McGrawHill, 2000.
- [8] Andrade C., Gonzalez J.A, Silicates Industry. 12(1982)289-294.
- [9] Bolzoni F. Bertolini L., T. Pastore, Pedferri P, Corrosion of Reinforcement in Concrete Construction, Cambridge: 1996.
- [10] Breit W., Schiesl P, International RILEM Workshop on Chloride Penetration into Concrete, France: 1995.
- [11] Bernhard Elsener Luca Bertolini, Pietro Pedferri, Rob Polder, Corrosion of Steel in Concrete, WILEY-VCH, 2004.