Estimation of Critical Chloride Threshold Value in Concrete by the Accelerated Corrosion Test

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ABSTRACT

It should be noted that the critical chloride threshold level is not considered to be a unique value for all conditions. This value is dependent on concrete mix proportions, cement type and constituents, presence of admixtures, environmental factors, reinforcement surface conditions, and other factors. In this study, the accelerated corrosion test for reinforcing steel was conducted by electrochemical and cyclic wet and dry seawater method, respectively and during the test, corrosion monitoring by half-cell potential method was carried out to detect the time to initiation of corrosion for individual test specimen.

For this purpose, lollypop and right hexahedron test specimens were made for 31%, 42%, and 50% of W/C, respectively, and then the accelerated corrosion test for reinforcing steel was executed.

It was observed from the test that the time to initiation of corrosion was found to be different with the water-cement ratio and accelerated corrosion test method, respectively and the critical chloride threshold values were found to range from 0.91 to 1.47kg/m³.

1. Introduction

The chloride threshold concentration for rebar corrosion initiation has received extensive attention over the last years. The chloride threshold concentration depends on several factors involving concrete mix proportions, exposure conditions, experimental technique, set up and rebar surface characteristics. As a consequence, many researchers have proposed critical chloride threshold ranges that take into account the relative influence of each of these many factors. However no particular threshold value for reinforcing steel corrosion in concrete has been universally accepted. In connection with this, the adoption of a single value for the purpose of specification or service life prediction is inappropriate.

The purpose of this experimental research is to evaluate the critical chloride threshold value of concrete test specimens exposed to artificial chloride environment. Under 31%, 42%, and 50% of water-cement ratios and 0.3, 0.6, 0.9, and 1.2kg/m³ of chloride contents by weight of concrete, respectively, lollypop and right hexahedron test specimens were manufactured, and then the accelerated corrosion test for reinforcing steel was conducted by electrochemical and cyclic wet and dry seawater method, respectively. Also, during the test, corrosion monitoring by half-cell potential method was carried out to detect the time to initiation of corrosion for individual test specimen.

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2. Experimental program

2.1 Materials and mix proportion

Ordinary portland cement (KS L 5201, Type 1) with a compressive strength in 28 days of 400 kg_f/cm^2 was used in the study. River sand and crushed stone of 25 mm maximum size were used as fine and coarse aggregates, respectively, with specific gravity of 2.60 for fine and 2.65 for coarse aggregate. In order to carry out the accelerated corrosion test for reinforcing steel in concrete, D13 and D19 deformed steel bars were used for lollypop and right hexahedron test specimens, respectively. A sulfonate naphthalene superplasticizer (SP) was used in this study to get a workable fresh concrete, with a pH value of 8. Substitute oceanwater was adopted and prepared in accordance with ASTM D 1141(Specification for Substitute Ocean Water). Lollypop and right hexahedron test specimens were prepared, having different water-cement (W/C) ratio of 31%, 42%, and 50%. To investigate the influence of W/C ratio on chloride ingress in concrete, chloride ions were added in series in the mix proportion of right hexahedron specimen in different magnitude, 0.3, 0.6, 0.9, and 1.2 kg/m^3 by weight of concrete.

2.2 Test specimens

The lollypop specimens were Ø100×150mm concrete cylinders in which a 13 mm diameter reinforcing steel was embedded at the side. The reinforcing steel was embedded into the concrete cylinder such that its end was at least 2 cm from the bottom and 2 cm at the extreme side of the cylinder.

Right hexahedron concrete specimens were 150×150×250mm in which 19 mm diameter reinforcing steel was embedded at the lower-center. All test specimens were placed at the normal temperature of about 20 ℃ under the vinyl cover 14 days before the start of the accelerated corrosion test and then, immersed in a reservoir with substitute ocean water.

2.3 Accelerated corrosion test and corrosion monitoring for reinforcing steel in concrete

In accelerated corrosion test of lollypop specimen, the periodic cycles of one day wet and one day dry condition was carried out. Also, the reinforcing steel was connected to a power supply that serves a constant voltage of 2V.

In accelerated corrosion test of right hexahedron test specimen, the periodic cycles of three days wet and three days dry condition were carried out. Every half-cell potential measurement was conducted on the last day of the dry condition to maximize the penetration of air in the specimen before a corresponding value is taken. This testing procedure is considered to simulate actual corrosion process of reinforcing steel in reinforced concrete structures. That is to ensure the supply of moisture during wet condition and air during dry condition to accelerate corrosion.

Half-cell potential measurements were conducted, following the ASTM C 876 guidelines to determine the likelihood of active corrosion. In this measurement, 54 and 285 testing days for lollypop and right hexahedron test specimens, respectively, were carried out up to now.

After depassivation of steel reinforcement, that is constantly attaining half-cell potential measurement of not more than -350 mV, the specimen was broken and the steel bar removed. Pitting was confirmed by visual observation and concentration of the total chloride just around the steel. Specified amount of concrete powder was extracted and analyzed in order to determine the critical chloride threshold value by Rapid Chloride Test.

3. Results and discussion

3.1 Corrosion monitoring for reinforcing steel in concrete

Fig. 1 shows the variation of half-cell potential measurements for lollypop test specimens under accelerated corrosion test. Six lollypop test specimens having 31%, 42%, and 50% W/C ratio are prepared. It was observed in the figure that there is large value of the potential at the initial reading. The half-cell potential values for various cases have a tendency to increase in early ages and then approaches to certain uniform values. These phenomena pertain to the hydration process of concrete that in this particular study, the lollypop test specimen potential stabilized after sometime. After the stabilization it is observed that the values gradually increase for all test specimens.

In the figure, after stabilizing, the half-cell potential measurements reached more than -200mV for all lollypop test specimens. As expected, test specimens with 31%, 42%, and 50% W/C ratio reached -350mV and continued to increase at an average of 48, 41 and 37 days, respectively, for the pairs.

Fig. 2(a) shows the half-cell potential measurements of right hexahedron test specimens with 0.3 kg chloride content depicts the evolution of corrosion rate of the rebar along the test. At 101 and 267 days the right hexahedron test specimen having 50% and 42% W/C ratio, respectively, measured -350 mV and continued to increase. On the other hand, right hexahedron test specimen with 31% W/C ratio have no sign of depassivation after 285 days of test which until now have a half-cell potential reading of more than -150 mV.

Fig. 2(b) shows the half-cell potential measurements of right hexahedron test specimens with 0.6kg chloride content. At 107 and 251 days the right hexahedron test specimen having 50% and 42% W/C ratio, respectively, measured -350 mV and continued to increase. On the other hand, right hexahedron test specimen with 31%W/C ratio have no sign of depassivation after 285 days of test which until now have a half-cell potential reading of -250 mV.

Fig. 2(c) shows the half-cell potential measurements of right hexahedron test specimens with 0.9kg chloride content. At 101 and 267 days the right hexahedron test specimen having 50% and 42% W/C ratio, respectively, measured -350 mV and continued to increase. On the other hand, right hexahedron test specimen with 31% W/C ratio have no sign of depassivation after 285 days of test which until now have a half-cell potential reading of more than -150 mV.

Fig. 2(d) shows the half-cell potential measurements of right hexahedron test specimens with 1.2 kg chloride content. At 95 and 173 days the right hexahedron test specimen having 50% and 42% W/C ratio, respectively, measured -350 mV and continued to increase. On the other hand, right hexahedron test specimen with 31% W/C ratio have no sign of depassivation after 285 days of test which until now have a half-cell potential reading of more than -150 mV.

It was observed from the test that the probability of corrosion occurrence was found to be high as water-cement ratio is large and chloride content by weight of concrete is much.

3.2 Estimation of critical chloride threshold value in concrete

In general, it could be regarded as the time to initiation of corrosion when the measurement value of half-cell potential reached less than -350 mV. According to this, it was observed that the time to initiation of corrosion was found to be different with water-cement ratio and chloride content by weight of concrete. As a result, the critical chloride threshold values of lollypop and right hexahedron test specimens were found to range from 0.91 to 1.27kg/㎥ and from 0.96 to 1.47kg/㎥, respectively.

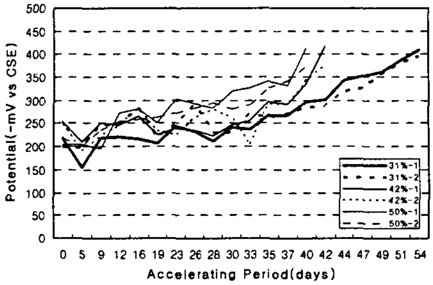
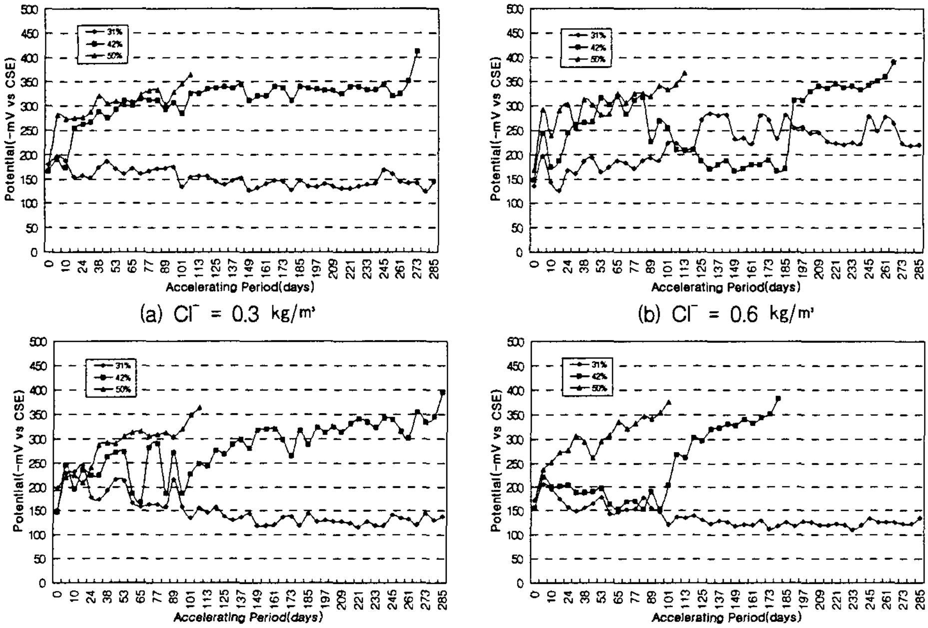


Fig. 1 Monitoring of Lollypop test specimens



(a) Cl^- = 0.3 kg/m³ (b) Cl^- = 0.6 kg/m³

(C) Cl^- = 0.9 kg/m³ (d) Cl^- = 1.2 kg/m³

Fig. 2 Monitoring of right hexahedron test specimens

4. Conclusions

(1) It was observed that the time to initiation of corrosion was found to shorten with increasing water-cement ratio and chloride content by weight of concrete for both lollypop and right hexahedron test specimens.

(2) It was observed that the critical chloride threshold values of lollypop and right hexahedron test specimens were found to range from 0.91 to 1.27kg/m³ and from 0.96 to 1.47kg/m³, respectively.

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