

Assessment of Mortar Corrosion by Sulphuric Acid

Tatsuo Kawahigashi

*Institute for Science and Technology, Kinki University
Kowakae, Higashi-Osaka 577-8502, Japan*

(Received, January 21, 2007)

Abstract

In order to study the corrosion mechanisms of water-cement system, cement mortar specimens were immersed in the sulphuric acid solution. Over the periods, changes to the roughened surfaces, mass change and neutralization depth were observed. Corrosion of cement mortar progressed through chemical reaction of sulphuric acid and ion transport in mortar. Relations between the environment operation of sulphuric acid and the corrosion (summation of chemical erosion and neutralization depth) of test specimens were presented. And an estimation of the corrosion of mortar in this environment was proposed from these results.

Key words: cement mortar, sulphuric acid, corrosion, mass change, erosion, neutralization depth

1. Introduction

The main results obtained by the previous reports [1] – [2] are summarized as follows.

In each environment, sulphuric acid ion decreased according to the immersion period of the test specimen. Especially, the rate of decrease in the early stages was remarkable compared to that for other periods.

It was assumed that the environmental operation could be assessed according to the accumulation value by hydrogen ion concentration or the disappeared sulphuric acid ion for unit area of test specimen. The damage was assumed as a summation with the corrosion and carbonation depth. Good correlation

existed between the operations and their respective damage levels.

The same degree of damage might not always be shown, even with identical operations (the mass decrease and the carbonation rate) because of different acid concentrations if a relation between operation and damage obtained from the specific acid environment was applied to another acid environment.

Therefore, detailed examinations are necessary for other subjects in this study. And, adding obtained new basic results for long term to previous study [1], the content of previous report was examined in this report.

Table 1 Experimental outline

Material	Ordinary Portland cement (specific gravity : 3.15) , river sand (specific gravity : 2.57)
Mix proportion	Water - cement ratio (W/C, %) : 40, 50, 60 , weight ratio of cement / sand : 1 / 3
Test specimen size	Φ25mm × 50mm
Curing condition	Water curing : 4 wk , air curing : 2 wk
Environment	Sulfuric acid solution (weight concentration (%) : 0.5, 3.0)
Measurement	Environmental operation : pH and ion concentration , mass change, corrosion (erosion and neutralization) depth

2. Experimental Outline

Experimental outline shown in Table 1 is almost same as previous report and items are as follows.

2.1 Materials

Mortar specimen was used as the water cement system. Materials used were a commercially available ordinary Portland cement (specific gravity: 3.15) for main cement and river sand (specific gravity: 2.57) as fine aggregate. Sulfuric acid was used the best available quality reagent as the environment.

2.2 Items of test specimen

The W/C (water cement ratios) of specimen was 40, 50 and 60% respectively. The mass ratio of the cement and river sand was a constant value of 1:3. Test specimen shape was a column with 25-mm diameter and 50-mm height. And the upper and bottom surfaces of specimen were painted with resin.

2.3 Environment and specimen condition

The initial concentrations of the sulfuric acid solution were 0.5% and 3%. The replacement time for old acid solution in tank with new solution was basically at every 1-wk or 2-wk until 4-wk. Thereafter, the new one. Regarding the standard mass of each test specimen, the resin coat weight was added to the specimen weight after curing in water for 4 wk. To assess the neutralization depth, for test specimens were measured using the following procedure.

The test specimen was taken out at 1, 2, 4, 8 and 16 wk from the start of exposure in solution and was cut using the dry cutter. Test specimens were cut

it was done every fixed period. Each environmental tank was kept covered to prevent evaporation from the solution surface in the indoor air environment.

2.4 Measurements

Test specimens by classified with group of water-cement ratio were immersed individually in the sulfuric acid tank. Items such as pH and ion analysis for environmental solution, and mass weight and neutralization depth were examined based on following conditions.

(1) Environmental operation (pH and ion concentration)

The time for measurement of the pH and sulfuric ion concentration were approximately every after 1 wk for 4 wk and every after 2 wk for 4–16 wk in all concentration cases. These measurements were done at the time of replacement of the old acid solution with the new acid. For each measurement, personal pH meter and ion analysis meter were used.

(2) Change of specimen (mass change and corrosion depth)

Each mass weight measurement was done at the time of replacing the old environment solution with respectively at right angles to the exposure surface. These cut surfaces were sprayed with phenolphthalein solution and were measured from the corroded surface to the boundary position of neutralization and non-neutralization. The value was subtracted from the diameter of non-neutralization zone from the initial diameter before exposure.

3. Results

In this report, some of these examination results are discussed as the following.

3.1 Environmental operation

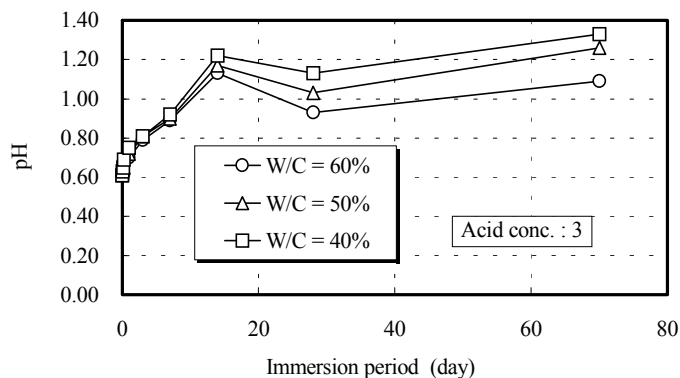
In the previous report, from a relative point of view, it was assumed that the immersion periods were "the first period" for 1 day from the start of immersion and "the long-term" after "the first period" in hr scale. In this case as long disposeure (immersion) period, it was assumed that "the first period (the early stage)" was for 4-wk from the start of immersion and "the long-term (the long stage)" was after "the first period" in this period.

The changes in the pH are and sulphuric acid ion

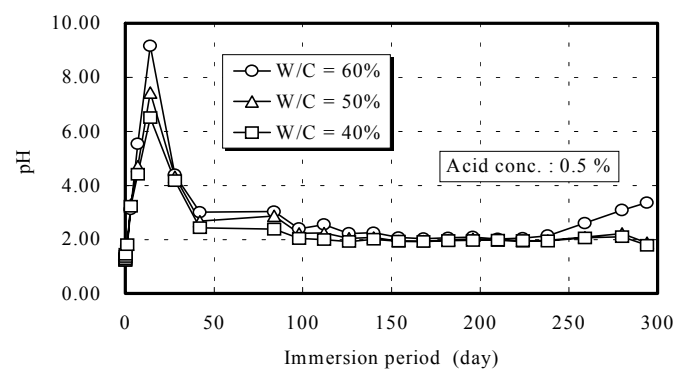
concentration in environment are shown in Fig.1 and Fig.2.

In each environment, initial concentration was set at 0.5% and 3% as described above.

In early stages, the pH increased and sulphuric acid ion concentration decreased from initial condition with immersion time in every environment. Almost changes are remarkable for early stages from after periods. These changes are greatly near at the early stage of immersion. And after the early stage, the rate of change is low. For over periods, there is no significant difference of W/C observed without little difference in this period scale.

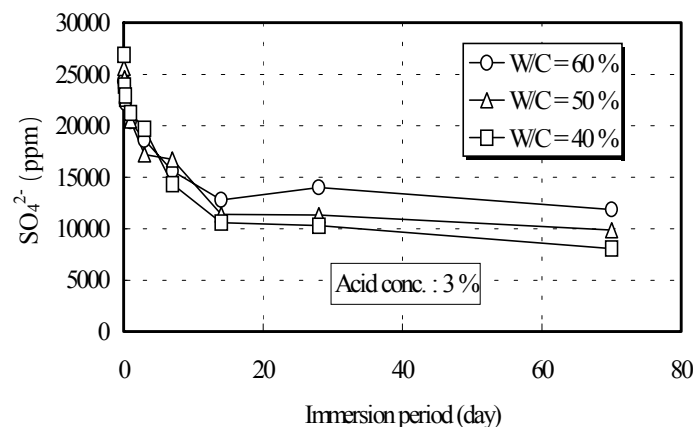


(a) Acid conc. : 3 %

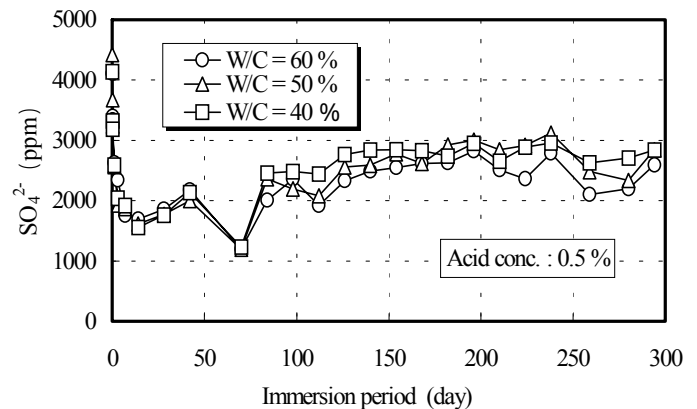


(b) Acid conc. : 0.5 %

Fig. 1 Change in pH of environment



(a) Acid conc. : 3 %



(b) Acid conc. : 0.5 %

Fig. 2 Change in SO_4^{2-} ion of environment

3.2 Changes of specimens

(1) Mass

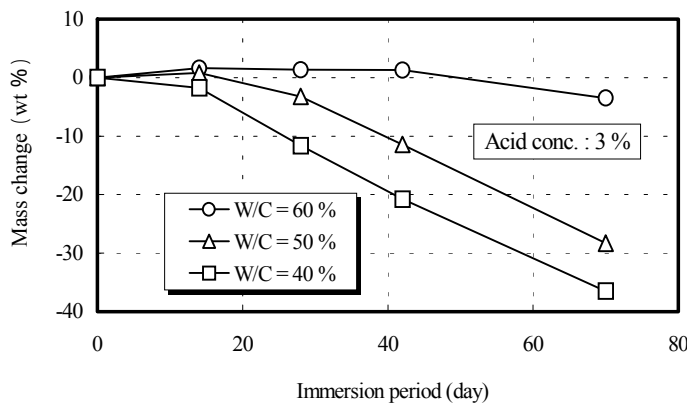
Changes in mass for all test specimens (samples) were observed with immersion period. These results are shown in Fig.3.

Differences in environment led to variations in the degree of mass. In general, a low W/C is so rich of cement component that induces intensive chemical reaction with sulphuric acid. Also, this tendency is remarkable at 3% sulphuric acid concentration. Therefore, looking at mix proportion factors, the mass loss at a W/C of 40 % and 50 % was larger than that at 60 %.

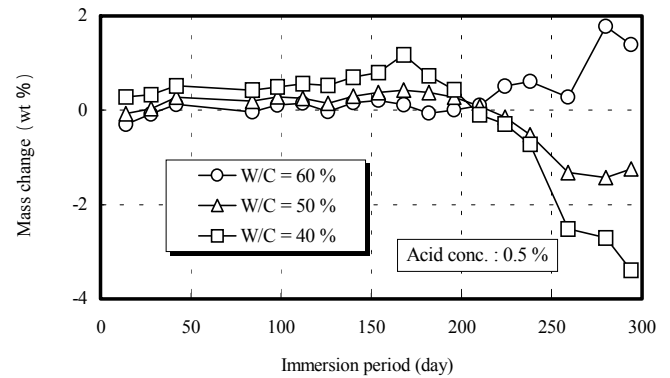
(2) Corrosion

The corrosion of test specimen was a summation of the mass variation (the erosive quantity) and the neutralization depth. These results are shown in Fig.4. According with long immersion term, the corrosion at a high W/C is larger than that at low W/C. Therefore, although a low W/C causes a large mass reduction than a high W/C from mass results, it is regarded that a low W/C is effective in preventing corrosion. The cause is regarded that a high W/C sample is consisted with more porous structure than a low W/C sample.

Therefore, a sample with a higher W/C is considered that sulphuric acid permeates easily into the interior of sample.

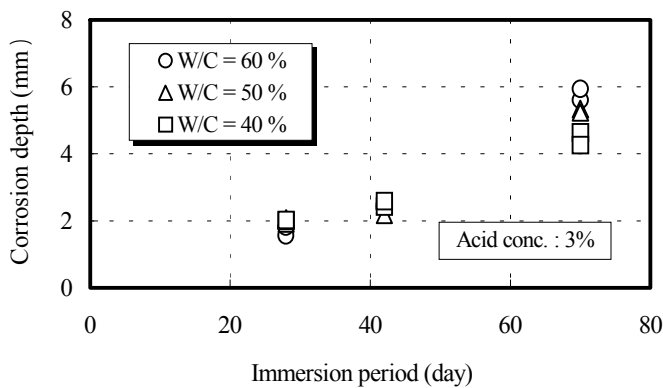


(a) Acid conc. : 3 %

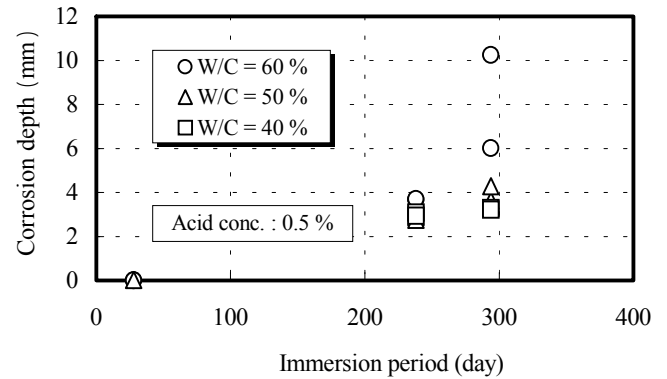


(b) Acid conc. : 0.5 %

Fig. 3 Change in mass of test specimen (sample)



(a) Acid conc. : 3 %



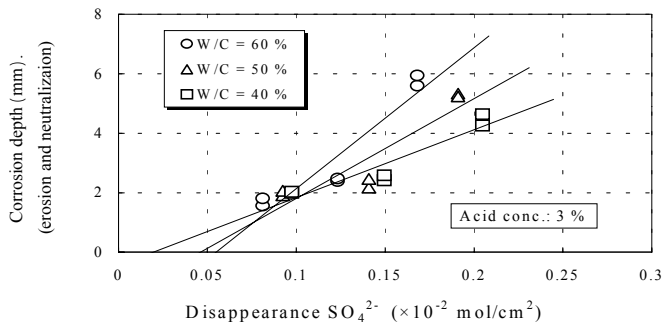
(b) Acid conc. : 0.5 %

Fig. 4 Change in corrosion (chemical erosion and neutralization) depth of test specimen (sample)

3.3 Operation and corrosion

As the way described in previous report, the value of environment operation was calculated for the test specimen unit area. On the other hand, the corrosion value of test specimen was described in “3.2 (2)”. Results from these measurements and calculation are shown in Fig.5.

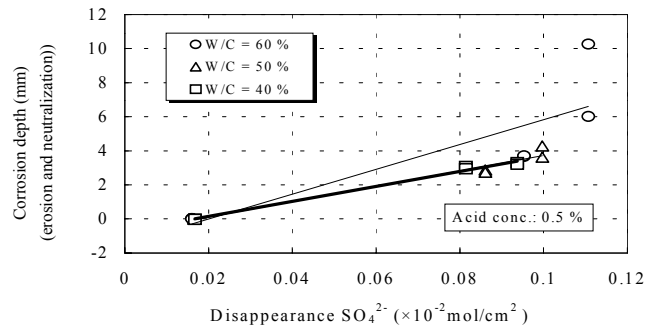
In the early period, the general relation showed no significant difference resulting from the different



(a) Acid conc. : 3 %

water cement ratio. However, the depth of the corrosion (erosion and neutralization) as the damage seems to increase concomitant with the accumulated value as the operations increase. Therefore, each relationship is regarded to be a good correlation.

And according with long immersion term, these correlations show the corrosion at high W/C was larger than at low W/C in the case of same operation value.



(b) Acid conc. : 0.5 %

Fig. 5 Relation between environmental operation and corrosion

4. Conclusion

In order to assess the corrosion of water-cement system, estimation was performed for long term. Environmental operation of sulphuric acid was estimated by the pH and ion measurement. And the corrosion was also performed simultaneously by the mass change and corrosion (chemical erosion and neutralization) depth measurement. The results shown by previous report were therefore estimated over long term, and have been evaluated in detail. Some conclusions from obtained results are as follows.

(1) In early stages, the pH increased and sulphuric acid ion concentration decreased from initial value with immersion time in every environment. Almost changes are more remarkable for early stages than long periods.

(2) Looking at mix proportion factors, the mass loss at a low W/C was larger than that at high W/C. On the

other hand, according with long immersion term, the corrosion at a high W/C was larger than that at low W/C. Therefore, although a low W/C specimen caused a large mass reduction than a high W/C specimen from mass results, it is regarded that a low W/C is effective in preventing corrosion.

(3) It was assumed that the environmental operation can be assessed according to the accumulation value by pH or the sulphuric acid ion for unit area of test specimen, and the damage was assumed as a summation with the corrosion depth. Good correlation existed between the operations and their damage levels.

Therefore, according with long immersion term, these correlations show the corrosion at high W/C is larger than at low W/C in the case of same operation.

References

- [1] T. Kawahigashi: Effects of sulfuric acid solution on cement mortar, Annual Reports by RIST, No. 19, 35-39, 2007.2.
- [2] T. Kawahigashi: Corrosion of Concrete under acid environment, Annual Reports by RIST, No. 16, 35-39, 2004.2.