Corrosion Deterioration Characteristics of Structural Steel

by Accelerated Exposure Test System under the Water

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ABSTRACT

Many infrastructures had been constructed during the high economic growth period in Japan. Around 40 years have passed since they constructed, and most of them have been deteriorated. A lot of steel structural members have been adopted not only in the coastal and port infrastructures but also in the small and medium river environments like as steel sheet piles for river walls in Japan. It is important to elucidate the corrosion behavior of the steel members under the sea water and the flesh water for maintaining the steel structures in these environments. In this study, a large size test system (so called, bubbling test system) was newly developed for accelerating the corrosion of structural steel under the water environment. By using this test system, a series of accelerated exposure tests were carried out for investigating the difference of the corrosion behaviors of structural steel between under the sea water and flesh water conditions. The acceleration coefficients of developed test system under the salt water condition were around 9, 18 and 23 compared with the splash zone, the submerged zone and the tidal zone respectively, compared with the results of field tests.

Key words: maintenance, corrosion, steel, sea water, fresh water, accelerated exposure test

INTRODUCTION

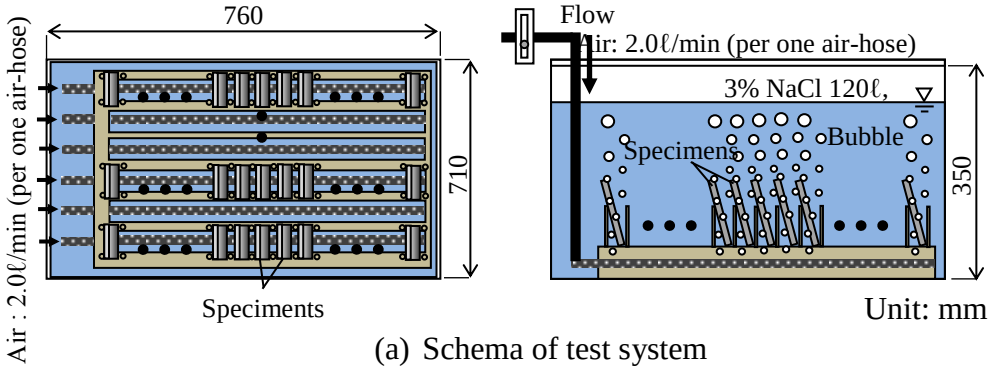
A lot of infrastructures were constructed in the period of high economic growth from 1950s to 1970s in Japan. Many of them have been aged and deteriorated. Management of these deteriorated infrastructures becomes a huge problem from the viewpoints of engineering and economy. In the cases of steel structures around the water area such as river, marine and coastal regions, a main cause of deterioration of them is corrosion. It is reported that a lot of steel piers and steel sheet piles used for shore protection in a river or under the sea are corroded1. It is difficult to predict the complicated corrosion behavior depending on several water conditions. Furthermore, it is hard to detect and monitor the corrosion of members under the water. Because of these difficulties, it is important to understand the corrosion behavior of steel structural members under the water conditions in maintenance of infrastructures around the water area.

In order to investigate and evaluate the corrosion characteristics of steel members under the water conditions, a standard method of an accelerated exposure experiment has been proposed by Japanese Society of Civil Engineers2. In this standard method, 16 steel plate specimens of which the dimensions are 150×70×10 mm can be tested at once. For making the accelerated exposure experiment more effective, a large size accelerated exposure experimental system based on the standard one was newly developed3. The size of the newly developed system was 6 times as large as the standard one. For verifying the performance of the newly developed experimental system, a series of accelerated exposure experiments on the steel plate specimens was carried out. The average thickness reduction, variation of the corrosion depth and the corrosion speed by the newly developed experimental system were examined.

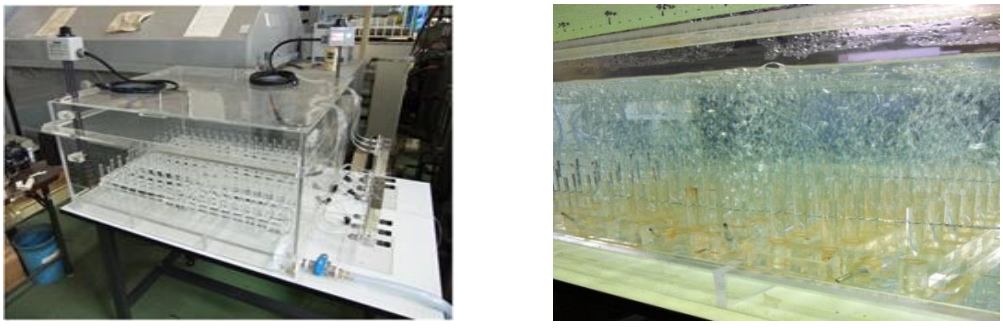
On the other hand, the above experimental method is simulating the environment under the sea water. However, there are many steel structures around not the sea water environment but the fresh water environment such as rivers and ponds. Therefore, a series of accelerated exposure tests were carried out by the developed system under the fresh water condition. By comparing with the test results under the sea water condition, the differences of corrosion behavior of steel members between the fresh water condition and the sea water condition was investigated in this study.

ACCELERATED EXPOSURE TEST SYSTEM

The newly developed experimental system is shown in Fig.1. The dimensions of the experimental system are 760×710×350 mm. It is filled with salt water (3%NaCl, 50 ℃, 120 ℓ). Carbon steel specimens are set on acrylic stands in the bottom of the experimental system. Air bubbles (2.0 ℓ/min) are supplied from hosepipes set below the stands for generating the water flow and keeping the density of dissolved oxygen. These conditions are kept during 28 days for accelerating the corrosion of the steel specimens2. The size of the newly developed experimental system is 6 times as large as that of the standard one2. By this system, 96 specimens in the maximum can be set at one time.



(a) Schema of test system



(b) Exterior of experimental

Figure 1: Newly developed test equipment

PERFORMANCE VERIFICATION OF ACCELERATED EXPOSURE TEST SYSTEM

For verifying the performance of the newly developed experimental system, a series of accelerated exposure experiments on the steel plate specimens were carried out. The material of the specimens was a general structural steel (SM400)4. The dimensions of the specimens were 150×70×6 mm. For evaluating the corrosion from the one surface of the specimens subjected to the water flow from the bottom of the water tank, another surface and the edges of the specimen were covered for anticorrosion. Fig.2 shows the set position of the specimens in the experimental system. In the figure, the red rectangles represent the carbon steel specimens and the white ones represent the acrylic dummy specimens. The number of the carbon steel specimens and the acrylic dummy specimens were 24 and 72 respectively.

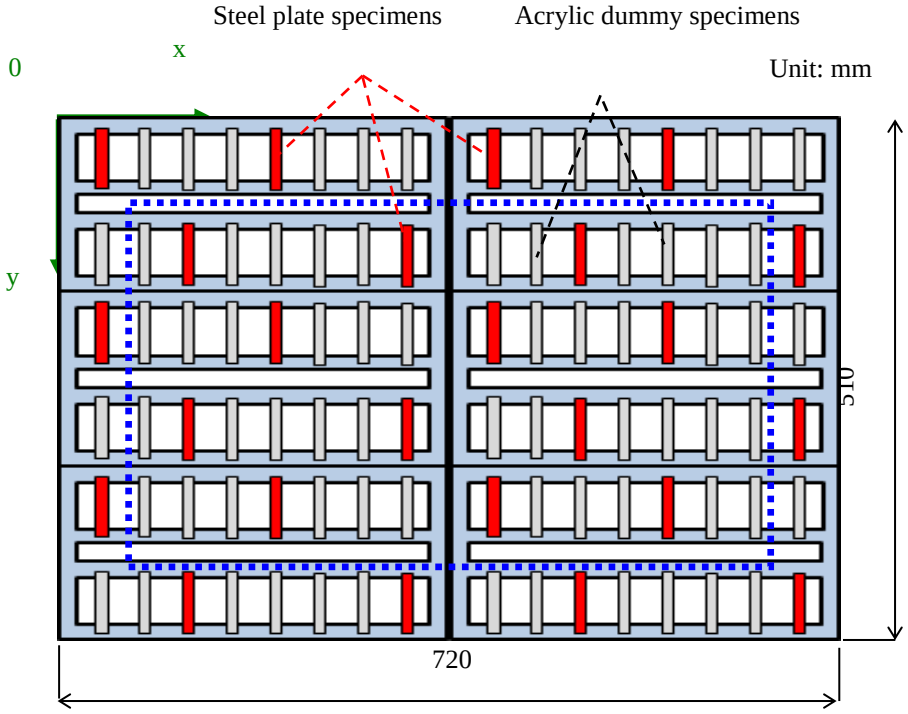


Figure 2: Arrangement of specimens

RESULTS

After the experiment during 28 days, the surface shapes of the specimens were measured by a laser depth meter. Fig.3 shows an example of surface conditions of the specimen. The degree of the thickness reduction differed on the surface of the specimens. The reason was possibly the removal of rust layer from the surface due to the bubble flow. The average thickness reduction of the specimens is 0.27 mm.

Fig.4 shows the relationship between the weight reduction and the location of the specimens. Near the side wall of the water tank (y=35 mm), the weight reduction of the specimen is smaller compared with that in the middle of the water tank. The average weight reduction of all specimens is 21.66 g, and the standard deviation is 2.40 g. The coefficient of variation is 11 %. The weight reductions of all specimens are within about ±10 % of the average weight reduction.

In the past study for another accelerated exposure experimental system5, the coefficient of variation of the weight reduction was about 10 %. Comparing the results by this experimental system with that by the past study, the accuracy of this experimental result is appropriate. Furthermore, when the experimental results are evaluated by only the specimens enclosed by the blue dotted lines in Fig.2, the coefficient of variation decreased to about 6 % although the average weight reduction does not almost change.

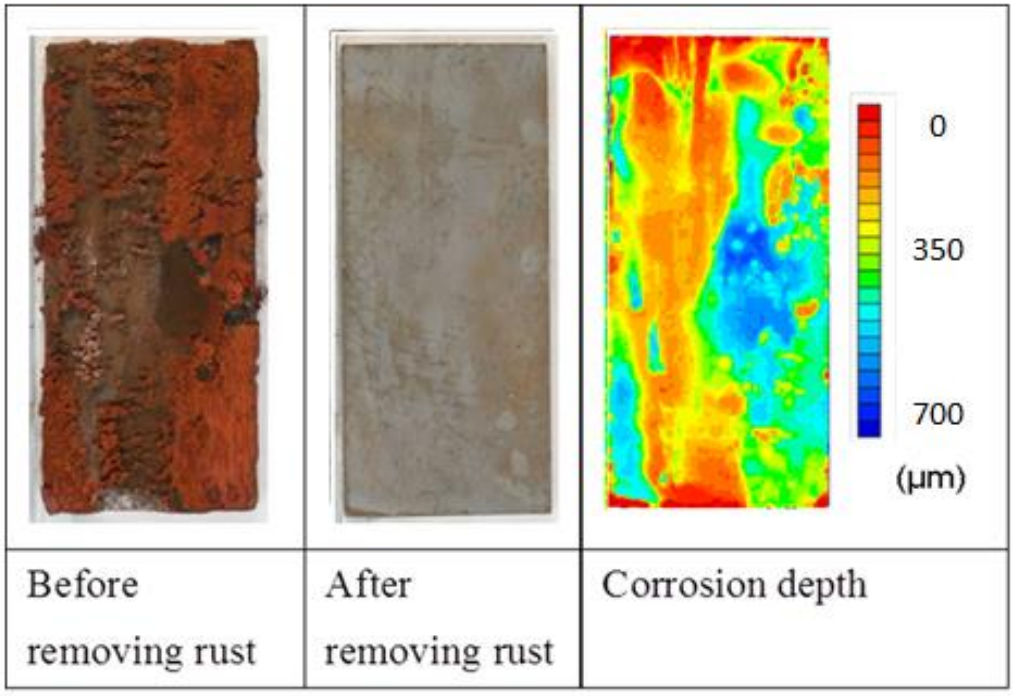


Figure 3: Example of surface conditions of specimen

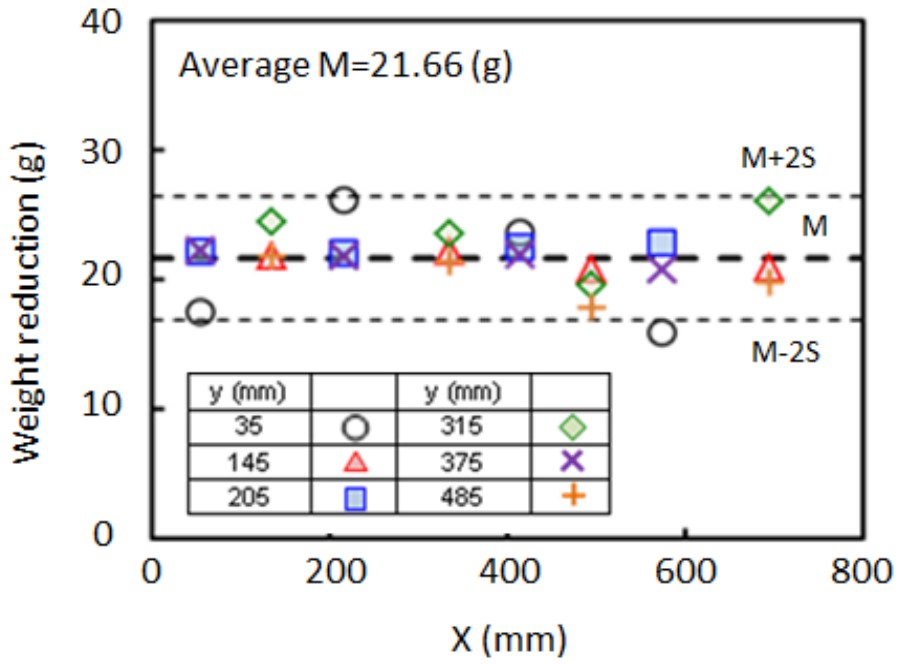


Figure 4: Relationship between weight reduction and location of specimens

CORROSION SPEED

The average thickness reduction which is converted from the weight reduction is 0.26 mm for 28 days. This value is almost the same as the result obtained from the change of the surface shape measurement (0.27 mm). This fact indicates the validity of the both measurement results. The corrosion speed is 3.45mm/year, when converting the average thickness reduction for 28 days by this experiment into that for one year. In the exposure experiment under the actual marine condition performed in the past research, the corrosion speed of steel plates in the tidal zone is about from 0.1 to 0.2 mm/year, and the one in underwater is about 0.2 mm/year6. It can be said that the corrosion speed by the newly developed accelerated exposure experimental system is almost 20 times as high as that under the actual environment under sea water.

ACCELERATED EXPOSURE TEST WITH FRESH WATER

The accelerated exposure test was also performed by using fresh water. The material and the dimensions of the specimens were the same as the test with salt water. The numbers of the specimens and the acrylic dummy specimens and the arrangement of them were also the same as the test with salt water. In this test, only the type of water is different from the test with salt water. In other words, the tank was filled with fresh water (50 ℃, 120 ℓ). Air bubbles (12.0 ℓ/min) were supplied from hosepipes embedded below the stands. These conditions were kept during 28 days.

Fig.5 shows the appearance of surface of the specimen after the test and the measured results by laser depth meter. The surface of specimen was uniformly corroded when compared with the result by salt water shown in Fig.3.

Fig.6 shows the relationship between the weight reduction and the locations of the specimens. The average weight reduction is 4.06 g. The coefficient of variation is 11 %. The average thickness reduction which is converted from the weight reduction is 0.05 mm. That is around 19% of the result by salt water.

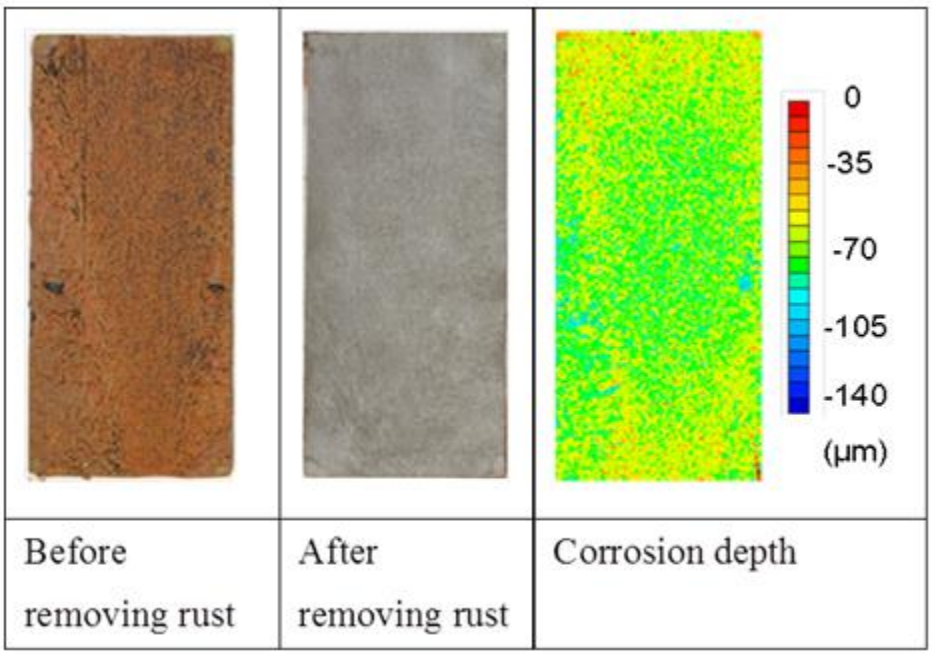


Figure 5: Relationship between weight reduction and location of specimens

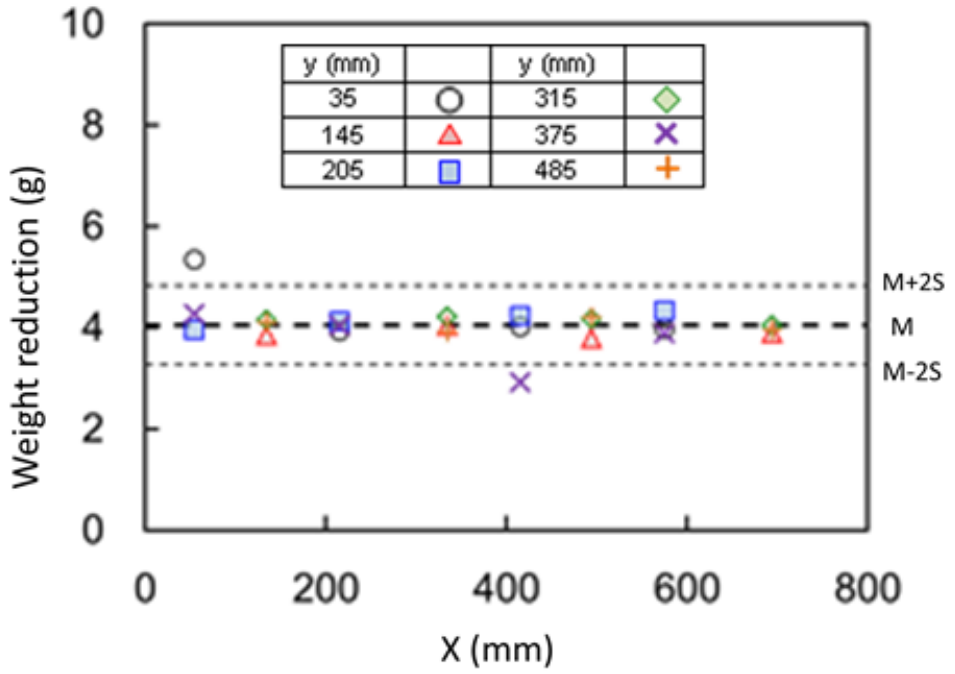


Figure 4: Relationship between weight reduction and location of specimens

CONCLUSIONS

A series of accelerated exposure tests were carried out for investigating the corrosion behavior of structural carbon steel both under sea water and fresh water conditions. The main results obtained are as follows.

(1) By the results of the newly developed accelerated exposure experimental system for the corrosion of the steel, the average thickness reduction of the steel plate specimens was 0.27 mm for 28 days under sea water. The coefficient of variation due to the location of all specimens was 11%, and it became 6% when the experimental results except the specimens located around the side walls of the water tank were evaluated. It was conformed that the newly developed experimental system had enough accuracy.

(2) The corrosion speed converted the weight reduction of the steel plates by the accelerated exposure experiment for 28 days was 3.45 mm/year. That was 20 times as high as that under the actual environment under sea water.

(3) The corrosion depth varied in a specimen under sea water. On the other hand, the surface of specimen corroded almost uniformly under fresh water. The bubble flow removes some part of the layer rust from the surface under sea water. This is possibly why the degree of the thickness reduction differed on the surface of the specimens under sea water.

(4) The average thickness reductions of specimen by the developed test system were 0.27 mm by the sea water and 0.05 mm by the fresh water, respectively. The thickness reduction by the fresh water was around 19 % of that by the sea water.

The corrosion depths of specimen by the developed test system were 0.27 mm by the salt water and 0.05 mm by the fresh water respectively. The corrosion depth by the fresh water was around 19 % of that by the salt water.

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