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EXPERIMENTAL STUDY FOR THE WETTING TIME OF WEATHERING STEEL PLATE WITH CHAMFERED EDGES

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In this study, the wetting time measurement of five weathering plates, which have three types of chamfered edges, were carried out for clarifying the superiority of drainage performance. The wetting state on steel surface was judged by measuring the electrical resistance at a center point near the plate edge. The inclination of all specimens was set to 2 % in this wetting time measurement. The protective rust (about 70 μm thickness) was generated all over the surfaces of specimens by the outdoor exposure test. From the experimental results, the linear-chamfered edges could shorten the average wetting time by 14~28 % than the non-chamfered edge, because the water-drops attached to the edges drip more easily. On upper surface, the drainage performance will be significantly influenced by the cutting size of chamfered edges.

Keywords: Wetting time, Electrical resistance, Drainage performance, Durability.

1 INTRODUCTION

The weathering steel bridges have high corrosion resistance even in a paint-less state because fine protective rust can generate all over the steel surface. The protective rust will be grown by repeating wetting and drying depending on the environmental situation. However, if the steel member was under the wetting environment for a long time, the layered-rust like piecrust would be generated instead of protective rust. This rust may reduce the durability and the load bearing capacity of structural members in the near future. Therefore, it will be thought that the simple geometric idea for improving the drainage on steel surface is important for earlier growth of protective rust.

In this study, the wetting time on a measuring point near the chamfered edges of 5 weathering plate specimens (SMA400W in Japanese Industrial Standard), which have the protective rust on all the surfaces, was measured by investigating the electrical resistance in order to improve the durability to undesirable corrosion. The average thickness of protective rust is about 70 μm through the outdoor exposure test for 16 months. All wetting time tests in this study were carried out in a draft-free laboratory under the constant condition for room temperature and humidity. The superiority of drainage performance for each structural detail (shape and cutting size of chamfered edges) was discussed based on the length of wetting time.

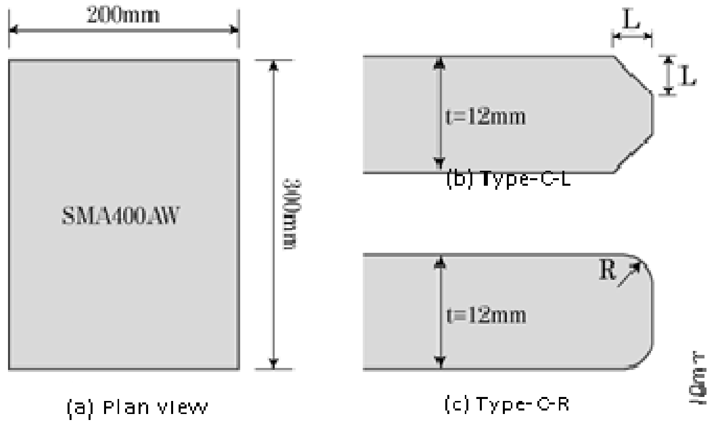


Figure 1. Dimensions of specimen.

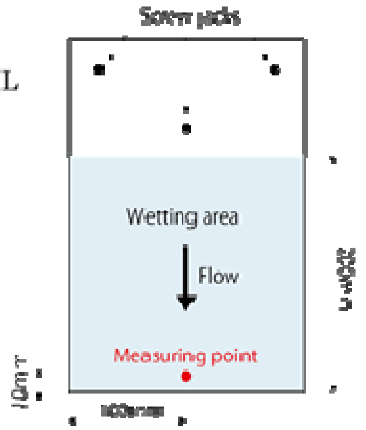


Figure 2. Measuring point.

2 OUTLINE OF TEST SPECIMENS

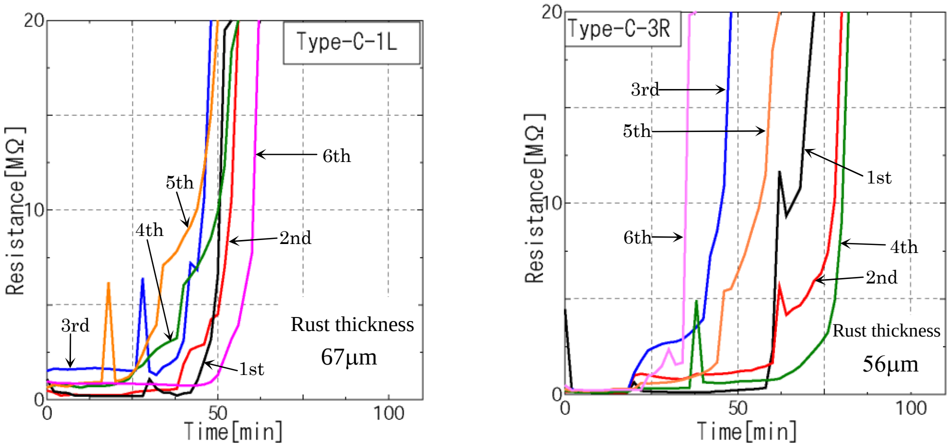
Figure 1 shows the dimension and shape of test specimens. All specimens have the same size (200 mm × 300 mm × 12 mm) as shown in Figure 1(a), but their edges are classified to 3 types depending on the shape of chamfered edge. In Type-C specimens, all edges in a specimen were chamfered by mechanical cutting before the outdoor exposure test, as shown in Figure 1(b) and (c). Type-C-L has linear-chamfered edges with 45 degrees on both sides, and the sizes of chamfered edge (L) are 1 mm and 2 mm (Type-C-1L, 2L). Type-C-R has round-chamfered edges with cutting radius R = 2 mm and 3 mm (Type-C-2R, 3R), respectively. In addition, a specimen with non-chamfered edges (Type-N) was prepared to compare the wetting time with that Type-C specimens.

The protective rust of all specimens was generated on all over the steel surfaces through the outdoor exposure test in an airy environment for 16 months. The thickness of protective rust is about 60~70 μm, and the grain diameter of rust is less than 0.6 mm.

3 WETTING TIME TEST BY MEASURING ELECTRICAL RESISTANCE

3.1 Measurement Method and Definition of Wetting Time

The rust is non-conductive material in the dry state, but the wetting rust can pass a certain amount of current on steel surface. From this feature, the wetting state of steel surface will be able to be evaluated from the value of electrical resistance (R_e) at the measuring point (Nishi *et al.* 2011). In this wetting time test, the electrical resistance on steel surface was measured by contact with 2 terminals (2 mm intervals) of a circuit tester to a measuring point on the center of downstream edge, as shown in Figure 2. The values of electrical resistance were recorded at the intervals of 1 minute. In Figure 2, test specimen was supported by 3 screw jacks, and the inclination of specimen was set to 2 % to downstream direction. Before the wetting time test on lower surface, two-thirds area of downstream side was humidified locally with constant amount of tap water by using an atomizer. The electrical resistance of measuring point will get higher gradually with time, and reaches an infinite value eventually. The wetting time was defined as the elapsed time until R_e reaches 20 MΩ from the results of preliminary investigation about the relationship between R_e and the drying state on steel surface.



(a) Type-C-1L. (b) Type-C-3R.

Figure 3. Examples of R_e-t curves on lower surface.

3.2 Environmental Condition for Wetting Time Test

In this study, it is very important to keep the environmental conditions constant as much as possible for relative comparison of each specimens. So, all wetting time tests were carried out in a windowless and calm laboratory under the constant condition for room temperature (T) and humidity (H). Before the wetting time tests, it was confirmed that the fluctuation of room temperature was less than 1 degree from preliminary monitoring results for 12 hours. And, the fluctuation of humidity was less than 1 % in the same way. In this test, environmental conditions were set to T = 21 degrees and H = 40 %.

4 RESULTS AND DISCUSSIONS FOR DRAINAGE PERFORMANCE

4.1 Lower Surface

In the case of lower surface, the wetting time at a measuring point will fluctuate depending on the number or size of some attached water-drops in the chamfered edge even if the environmental condition was almost constant in testing. From this reason, the wetting time tests under the same conditions were repeated 6 times for every specimen, and the superiority of drainage performance for each chamfered edges was discussed from the average wetting time and variation coefficient of these results.

Figure 3 shows the characteristic examples of relationship between the electrical resistance (R_e) at a measuring point and the elapsed time (t). The wetting time of each specimens equals to the elapsed time when R_e reached to 20 MΩ. From these figures, you can notice firstly that all R_e-t curves have similar behavior. Though R_e is almost constant during several tens of minutes after the beginning of the test, R_e would be increased rapidly at certain times. This fact will reflect the drainage process including the dripping from downstream edge and evaporation about the stagnant water on lower surface. In Figure 3(a) for linear-chamfered specimen, all R_e-t curves and each wetting time were very close with each other. From this result, the number or size of attached water-drops on the chamfered edge will have little influence on the length of wetting time. However, the wetting time and Re-t curve in round-chamfered specimen (Figure 3(b)) were varied widely depending on each experimental round. This was done because the number of attached water-drops is larger than that of linear-chamfered specimens as shown in Figure 4. Also, these water-drops would be generated randomly on the downstream edge. If the number of these attached water-drops was larger, the wetting time also will become long naturally. From this result, the water-drops will be easy to attach on round-chamfered edge than linear-chamfered edge.

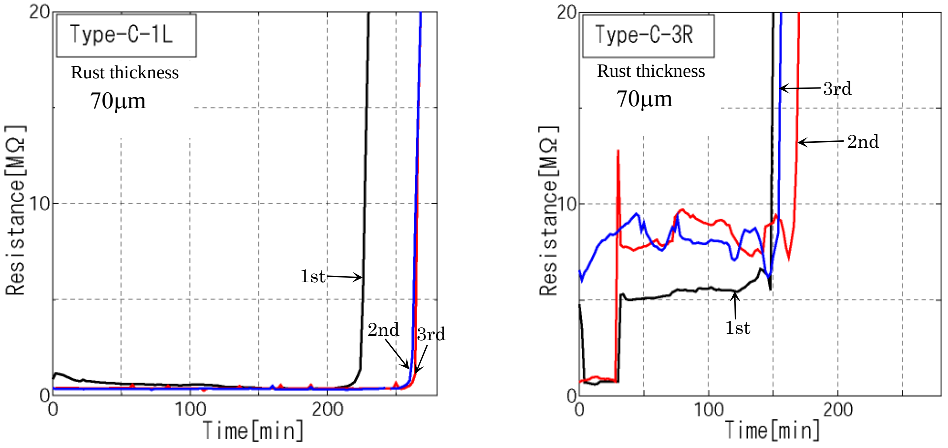
(a) Type-C1-L. (b) Type-C3R.

Figure 4. Examples of attached water-drops (20 minutes later).

Table 1. Wetting time on lower surface.

Type of specimen	Wetting time in each experimental round [min]						Average wetting time [min]	Variation coefficient [%]
	1st	2nd	3rd	4th	5th	6th		
C-1L	54	56	48	56	50	66	55.0	10.44
C-2L	46	50	52	44	40	44	46.0	8.70
C-2R	48	64	82	32	62	66	59.0	26.46
C-3R	72	80	48	82	62	38	63.7	25.48
N	52	46	76	74	68	68	64.0	17.40

Table 1 shows the wetting time of all the specimens. From the comparison of the average wetting time between Type-C-L and Type-N, it was shown that the linear-chamfered edges could shorten the wetting time by 14~28% compared with the non-chamfered edge, because the water-drops attached to edge will drip easily. For the cutting size of chamfered edge (L), the wetting time of Type-C-2L was shorter by 16% than Type-C-1L. Therefore, the linear-chamfered edge with larger size was shown to be effective in the improvement of drainage performance in lower surface. Though the reason why the wetting time of Type-N tends to become longer (similar to Type-C-R) could not explain directly from these wetting tests, the most suitable cutting angle, which will be related to surface tension near the cutting boundary, may exist for the earlier dripping of the attached water-drops.



(a) Type-C-1L (b) Type-C-3R

Figure 5. Examples of R_e-t curves on upper surface.

4.2 Upper Surface

The wetting situation on upper surface differs fundamentally from lower surface in that the surface water ponding is generated near the downstream edge. This surface ponding is generated widely due to surface tension from the boundary of chamfered edge to the lower half of specimen. Therefore, it will be important to facilitate the dripping of surface water for shortening the wetting time. On upper surface, the wetting time tests under the same conditions were repeated 3 times for every specimen.

Figure 5 shows the characteristic examples R_e-t curves on upper surface. From the comparison of figure (a) and (b), you can find that the behaviors of R_e-t curve differ between the linear-chamfered edge and round-chamfered edge in the range of $t < 150$ minutes. These fluctuations in Type-C-3R indicate that the water of surface ponding is dripped continually from round-chamfered edge. As the result, it can be thought that the average wetting time of Type-C-3R became shorter by 38% than that of Type-C-1L. Table 2 shows the wetting time of all the specimens. From the comparison with the average wetting time of Type-N, the superiority of drainage performance will not be able to be expected for Type-C-1L and 2R which have small cutting size of chamfered edge, because the average wetting time of Type-C-1L and 2R became longer than that of Type-N. However, the average wetting time for Type-C-2L and 3R, which have large cutting size of chamfered edge, was shorter by about 12~22% than that of Type-N. From these results, it is thought that the drainage performance on upper surface will be significantly influenced by the cutting size of chamfered edges. On the effect of the shape of chamfered edge on the drainage performance, though Type-C-3R seems to be a little favorable than Type-C-2L, the difference of the average wetting time of both was only about 10%. From the experimental results on upper surface, though the effect of the shape of chamfered edge to the wetting time was not much different, it is thought that larger cutting size of chamfered edge should be applied to the weathering steel members in order to improve the drainage performance.

Table 2. Wetting time on upper surface.

Type of specimen	Wetting time in each experimental round [min]			Average wetting time [min]	Variation coefficient [%]
	1st	2nd	3rd		
C-1L	230	268	268	255.0	7.02
C-2L	162	218	154	178.0	16.00
C-2R	260	200	228	229.3	10.69
C-3R	150	170	156	158.7	5.28
N	164	190	258	204.0	19.43

5 CONCLUSIONS

In this study, the wetting time test of 5 weathering plates, which have 3 types of chamfered edges, were carried out by measuring the electrical resistance of upper and lower surfaces with protective rust. And, the superiority of drainage performance for each structural details (shape and cutting size of chamfered edges) was discussed based on the length of average wetting time from repeated wetting time tests under the same environmental situation. The main conclusions obtained from the experimental results are as follows;

(1) Linear-chamfered edges could shorten the wetting time by 14~28% compared with the non-chamfered edge, because the water-drops attached to the edge will be easy to drip.

(2) Linear-chamfered edge with larger size was shown to be effective in the improvement of drainage performance on lower surface.

(3) On upper surface, though the effect of the shape of chamfered edge to the wetting time was not much different, the wetting time on chamfered edge with larger cutting size was shorter by 12~22% than that on non-chamfered edge.

References

Aso, T., Goto, S., Tabata,H., and Miyamoto, A., Study on Corrosion Factors of Weathering Steel Bridges Based on On-site Observations, *Journal of Japan Society of Civil Engineers*, 63(1), 460-468, 2007.(In Japanese).

Kaita, T., Goto, S., Takahashi, K., and Fukuda, T., The Measurement Test of Wetting Time for Weathering Steel Plates Focusing on Chamfered Edges, *Proceedings of annual conference of the Japan Society of Civil Engineers*, I-190, 379-380, Sep, 2013.(In Japanese).

Nishi, T., Hasegawa, A., Iwasaki, E., and Miura, M., Consideration for Wetting Time Measurement of Corroded Steel Members by Using the Direct-current Resistance, *Proceedings of annual conference of the Japan Society of Civil Engineers*, I-590, 1179-1180, Sep, 2011.(In Japanese).