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EFFECTS OF RESIDUAL RUST ON STRENGTH RECOVERY OF CORRODED STEEL PLATE REPAIRED WITH PATCH PLATE

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In Japan, there have been found a lot of corrosion damages recently in steel bridges aged for fifty or more years. If the strength of a steel structure is decreased by serious corrosion damages, the structure must be repaired to ensure its safety. In order to supplement the strength loss of a steel member with local corrosion, steel plate bonding method is often adopted, where the corroded area is covered with steel plate bonded by adhesive. In this case, surface preparation is the most important issue to bond the cover plates completely. In this method, surface preparation is the most important issue to bond the cover plates completely. However, it is quite difficult to completely remove rust and wastes in the fieldwork of surface preparation. Thus, this paper presents recovery effect of local corroded steel plate by steel plate bonding method when rust is not completely removed. Specimens are rectangular steel plates with irregular surface which imitated local corrosion in the center of plate. Then rust is also imitated rather than actual one to quantitatively evaluate the recovery effect. Axial tensile tests were conducted for these specimens repaired with patch plate. Then, the size of patch plate and amount of rust were changed and investigated how these differences affect the peeling off of the patch plate.

Keywords: Corrosion, Adhesive, Partial repairing, Tensile test, Surface preparation.

1 INTRODUCTION

Corrosion is a common damage in the maintenance and management of steel structures. When corrosion becomes serious, plate thickness decreases and may become unsafe. Therefore, the countermeasures to keep the structure safe are very important. In order to prevent occurrence of corrosion, painting etc. is generally applied, but it may deteriorate earlier than expected as a result corrosion occurs. In recent years, a repair method of attaching patch plates by adhesive against such damage was studied (Morishita *et al*. 2011). In addition, it is actually confirmed that this repair method has the strength recovery effect. The specimens used in these researches were subjected to blasting on the whole surface to ensure adherence of the adhesive sufficiently. However, it is difficult to perform blasting in the actual field. Therefore, in reality, surface preparation is carried out using power tools in many cases. In addition, in that case, it is very difficult to completely remove rust. In addition, in the actual field, for example, corrosion progresses from the web to large part of the flange of the plate girder, and since the corroded area is too wide, it may not be possible to cover the whole area with the patch plate. In such a case, it can be expected to repair partially only for the dangerous corroded area in order to compensate enough bearing capacity. Therefore, in this paper, the effects of residual rust when repaired by a general method is described at first, then the effects of residual rust when repaired by partial patch plate is also described.

2 TEST SPECIMEN AND OUTLINE OF EXPERIMENT

The test specimens are rectangular steel plates with 1,100 mm in length, 100 mm in width and 12 mm in thickness. After repairing with patch plate, static tensile test was conducted by displacement control at a test speed of 0.50 mm/min. Then, the effective length between chucks of the testing machine is 900 mm.

2.1 Specimens Repaired by General Method

Pseudo corrosion was made at the center of both sides of the specimens. The range of corrosion is 250 mm in length and 100 mm in width, and the thickness contour diagram and the average thickness distribution are illustrated in Figure 1. These corrosions are made artificially by drilling due to “surface generation method” developed by Fujii *et al*. (2004).

Residual rust in the corrosion range was simulated using clay. As shown in Figure 2, the ratio of residual rust was designed into four categories (98 %, 41 %, 25 % and 0 %). This ratio was computed by image analysis of photographs. Residual rust was placed in the recess of corroded range, it was assumed rust in the recess of the cross-section defect due to corrosion which cannot be removed with the power tool at the time of surface preparation. Residual rust was also placed on the back surface in order to have the same ratio as the surface. Sandblasted steel plate was used as the patch plate. The sand blasted steel plates have 100 mm in width which is the same as the base plate, and the length is 400 mm with the fixation length according to the general design method.

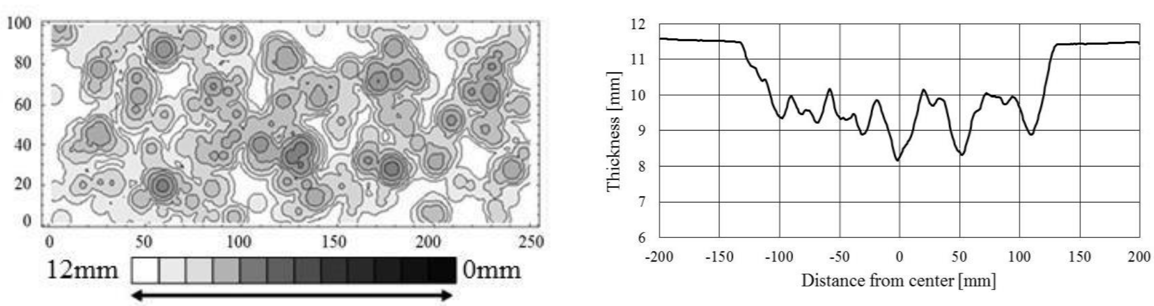

Figure 1. The thickness contour diagram (left) and the average thickness distribution (right).

The plate thickness was determined to be 3.2 mm based on Eq. (1) in order to compensate for the defect in the minimum cross-sectional position of the base material by the two patch plates. Then the patch plate was bonded with epoxy resin.

$$T_C \geq \frac{T_c - T_{min}}{2} \tag{1}$$

T_C: thickness of patch plate, T_0: original thickness of base plate, T_{min}: minimum cross-sectional average thickness of the base plate

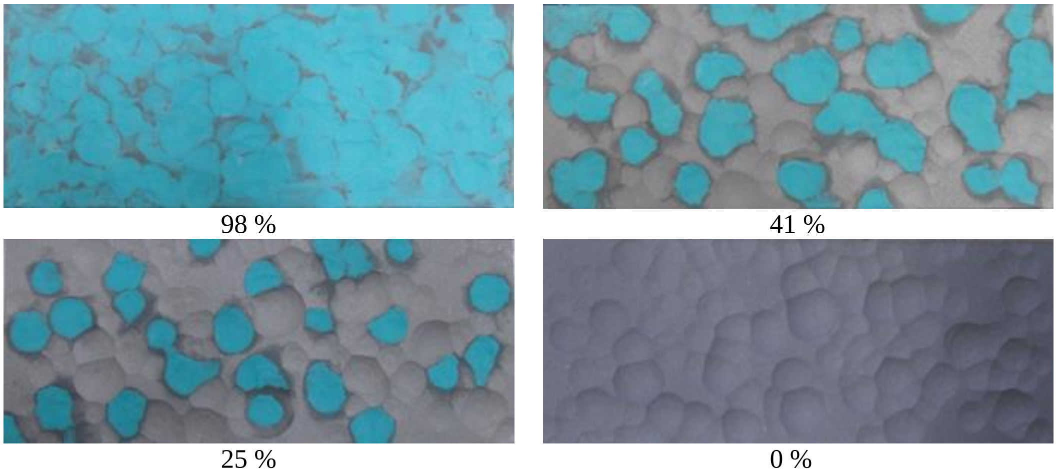

Figure 2. The ratio of residual rust (residual rust are shown in blue).

2.2 Specimens Repaired by Partial Patch Plate

The position of Pseudo corrosion was the same as the abovementioned specimens, but the range was expanded to 400 mm in length for partial repairing. The thickness contour diagram and the average thickness distribution are illustrated in Figure 3.

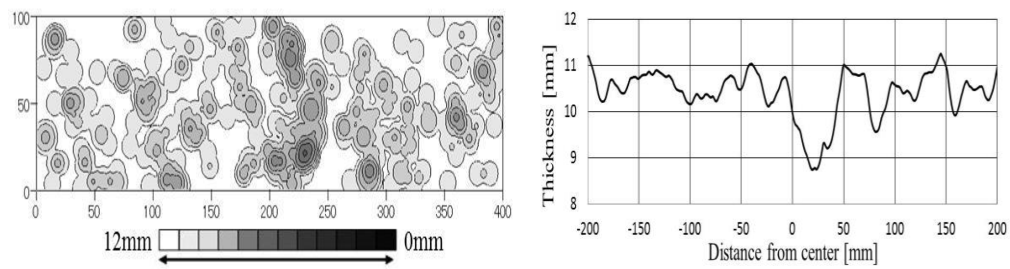

Figure 3. The thickness contour diagram (left) and average thickness distribution (right).

In this specimen, residual rust in the corrosion range was simulated using the tape. This is because there was a problem that oil might come out of the clay after adhesion of the specimen in Section 2.1. The ratio of residual rust was also designed into five categories (33 %, 23 %, 10 %, 6 % and 0 %), and this is the ratio for the range of patch plate (in other words the adhesion area) not for the corroded range. Moreover, the patch plate tends to peel more than general method because it adheres only to the uneven part in the partial repair and consequently it is considered that the patch plate is easy to be affected by the residual rust. Therefore, the ratio of residual rust is at most approximately 30 % as shown in Figure 4. The patch plate was also sandblasted steel plate, and the length of patch plate is 200 mm because it is aimed at partial repairing. The thickness was also set to 2.3 mm based on the Eq. (1).

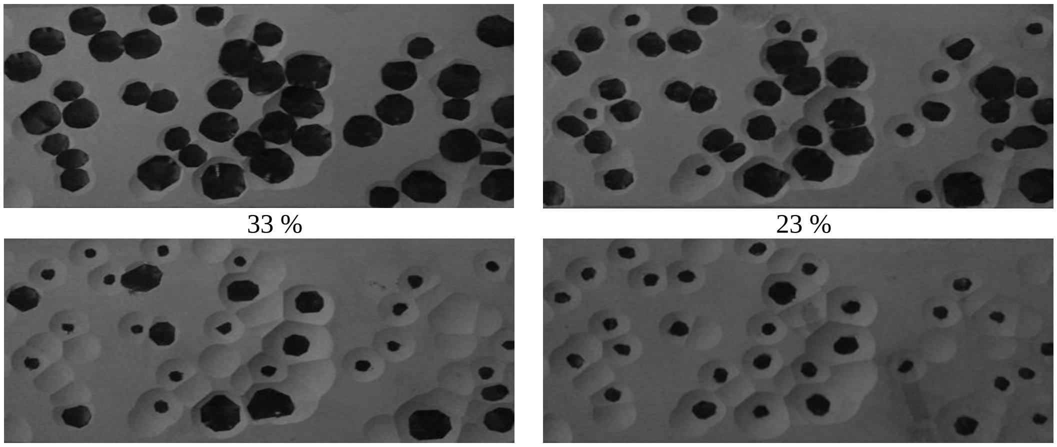

Figure 4. The ratio of residual rust (residual rust are shown in black).

3 RESULTS

3.1 Result of Specimens Repaired by General Method

Load versus elongation curves are illustrated in Figure 5. It is noticed from Figure 5 that the inclination of the curve became smaller around 240kN in the non-repaired specimen, but the yield load of repaired specimens was larger beyond this load.

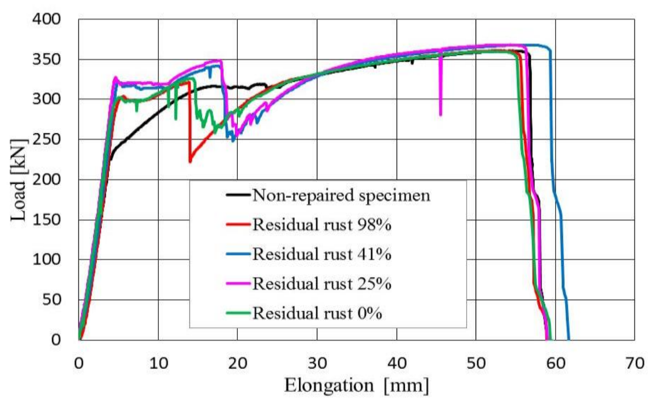

Figure 5. Load versus elongation curves.

In addition, it can be observed that the load of repaired specimens suddenly dropped at the elongation around the 15 mm. This means that the patch plate peeled off. The maximum load before peeling of all repaired specimens was larger than the theoretical yield load (246 kN) of non-corroded plate calculated from the material test, it suggests that these specimens have sufficient repair effect regardless of residual rust.

Figure 6 shows the strain distribution of base plate at 250 kN. In this figure, the center part of non-repaired specimen was yielded and the strain becomes very large, but the strain of the repaired specimen reduced in the corroded range. Moreover, the strain reduced regardless of the amount of residual rust. Therefore, it can be seen that this repair method, which was carried out by general method is effective even if it has residual rust also from the above.

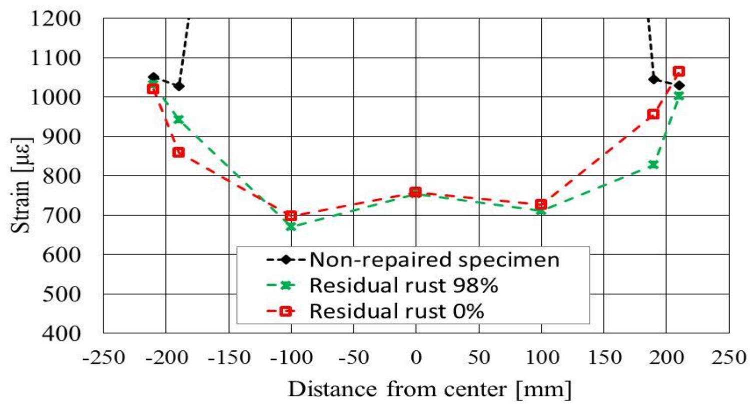

Figure 6. Strain distribution at 250 kN.

3.2 Result of Specimens Repaired by Partial Patch Plate

Relations of maximum load before peeling and ratio of residual rust are illustrated in Figure 7. First, even as for partial repairing, it is noticed that the strength recovered to near the yield load of non-corroded steel plate. However, the load decreased if there was even slightly residual rust. The load decreased by approximately 10 % for specimens with residual rust around 30 %. The reason for this is considered that cohesive failure occurs in adhesive layer if it is adhered firmly, but when the residual rust increases, interfacial failure that occurring between the adhesive and steel surface is easy to occur.

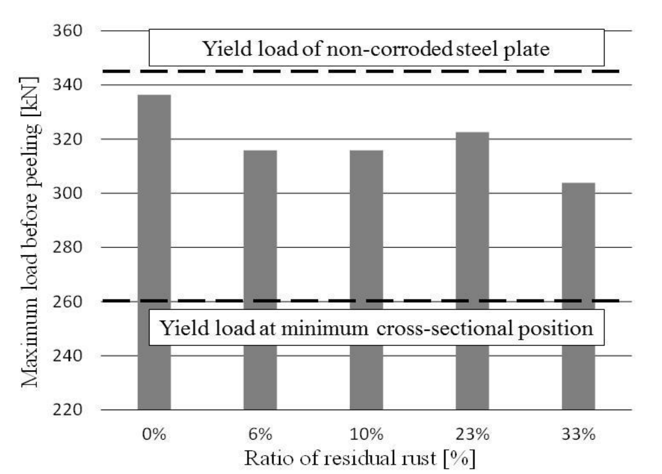

Figure 7. Relations of load and residual rust.

Thus, it seems that residual rust promotes peeling in partial repairing; nevertheless none of the specimens extremely peeled off earlier, and the load exceeded the yield load at minimum cross-sectional sufficiently. Therefore, it infers that it is possible to compensate for design load, although it is slightly affected by residual rust. In addition, although the specimens of section 3.1 had residual rust in the corroded range and the adhesion strength of corroded range probably weak, it did not affect peeling. The reason for this is considered that the interface between non-corroded part at sides and the patch plate was firmly adhered.

4 CONCLUSION

In this paper, it is investigated that the influence of residual rust after surface preparation on the premise that repair by patch plate was effective. The conclusions are shown below.

This repair method had the effect of reducing the strain in the corroded range of the base plate regardless of the residual rust. Furthermore, it is considered that if the corroded steel member is repaired by a general method, it was not peeled at elastic region and the force was transmitted sufficiently form the base plate to the patch plate. As a result, the maximum load before peeling of all repaired specimens was larger than the yield load of non-corroded plate regardless of the amount of residual rust. This is because it was adhered sufficiently in the adhesion range outside the corrosion range which has the role of transmitting the force. In other words, even if rust in the corrosion range cannot be removed, it is important to sufficiently perform the surface preparation of the adhesion range of non-corroded portion.

In addition, in the partial repair, although the strength recovery was achieved, the patch plate is liable to brittle peel off due to residual rust. This is because interfacial failure that occurring between the adhesive and the steel surface easily occurs due to residual rust. In this paper, it seems to be said that it is better to remove at least 80 % of rust in the adhesion range. However, the maximum load before peeling of the repaired specimens was 40 kN or more lager than the yield load of the minimum cross-sectional position in the non-repaired specimen in any case. Thus, it is considered that strength recovery is possible even with partial repair. Therefore, it is advisable to carefully decide whether to implement or not, depending on the work environment and the useful life of the target structure etc.

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