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EFFECT OF SURFACE PREPARATION GRADE ON REPAIR BY MEANS OF COVER PLATES AND ADHESIVE

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There are a lot of corroded steel bridges, which have to be prolonged its life in Japan. Corroded members in these bridges generally have local corrosion damages, and are often repaired by covering on the corroded area with steel plates in order to rehabilitate the strength. Recently, adhesive such as epoxy resin is often used for bonding the cover plates made of steel or CFRP, even though high-tensile bolts or welding have been adopted conventionally. In this case, surface preparation is the most important issue to bond the cover plates completely. However, complete removal of rust and wastes are quite difficult in the fieldwork of surface preparation. This paper presents recovery effect of local corrosion damage by means of covering method used by adhesive when the rust is not completely removed. Axial tensile tests were conducted for rectangular steel plates of 1,100mm x 100mm x 12mm with 400mm length of corrosion-surface-unevenness on the both surfaces, and the defects of surface preparation are made by putting tape paper at the damaged area. Then various sizes of the repair plates are bonded to consider the influence to repairing. From the test results, the ultimate strength decreased 7-10% compared with non-rust state when the defect area rate was about 30%.

Keywords: Corrosion, Adhesive repair, Steel prate, CFRP, Partial repairing.

1 INTRODUCTION

Currently, aging of infrastructure constructed in 1970s has become a social problem in Japan. The damage of a steel bridge is roughly categorized into corrosion and fatigue, where corroded steel has been conventionally repaired by cover plates used high-tensile bolt or welding. On the other hand, adhesive is recently being expected for bonding cover plates such as steel plate and CFRP (Carbon Fiber Reinforced Plastics), and CFRP has been sometimes used in real structures.

In this case, it is necessary to remove completely rust and dusts in corroded area and non-corroded area around the corroded area, in order to bond cover plates firmly. However, when the bonded area is too large, such as corroded area occurred most of the flange in a plate girder, it may not be so easy to bond adequately to the area. Therefore, in such a case, it can be expected to repair partially against only the dangerous corroded area so as to bear the design load. Furthermore, it is also not easy to remove the rust perfectly by electric tools such as a grinder. In this paper, we investigate the effects of the repairing with partial cover plate and the effects of incomplete surface preparation in order to create a basic data for establishment of design method in practice.

2 EXPERIMENT[1] TO CHANGE ADHESIVE LENGTH

We performed a static tensile testing of the specimens, which are subjected to simulate corrosion based on the Corroded Surface Generation Model[1)]. In this model, thinning due to corrosion is reproduced by scraping surface of undamaged steel plate by endmill. Thus, it is able to evaluate the repair effect quantitatively by using a number of specimens with the same decrease.

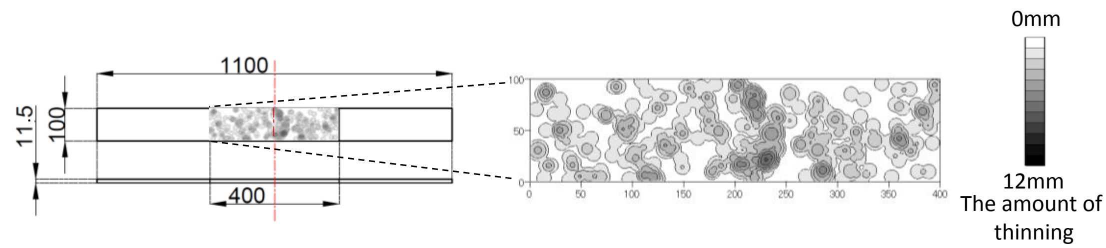

Figure 1. The details of decreased base steel.

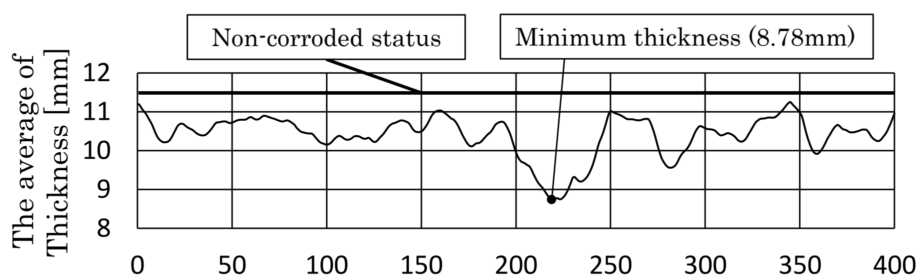

Figure 2. Profile of reduced average thickness.

Table 1. The detail of base steel, repair steel, CFRP, and adhesive.

	Thickness [mm]	Yield stress [N/mm^2]	Tensile strength [N/mm^2]	Young's modulus [kN/mm^2]
Base steel	11.5	296	441	205
Repair steel plate	2.3*	326	436	203
Repair CFRP plate	0.143x4*		1900	640

* Per side.

Name	Application		Compression shear strength [N/mm^2]
E258	Bonding steel		27.5
FP-N9	Bonding CFRP	Primer	18.2
FB-E9S		Unevenness modifying	16.7
FR-E9P		impregnating	15.4

Figure 1 shows the details of the specimens, and the designed average thickness of the cross-section is shown as Figure 2. It was verified that the reduced thickness of each specimen was nearly same as designed thickness by measuring with a laser measuring instrument. The average of reduced cross-sectional area at the 219mm position is minimum with value of 8.78mm,

[1] Fujii, K., Kaita, T., Nakamura, H., and Ario, I., A model generating surface irregularities with consideration of corrosion progress in aging, Japanese Society of Civil Engineers, 50A, 657-665, 2004.

therefore it is decided to adhere repair plates around this position. In this section, both methods (steel plate and CFRP) were implemented by five types of repair length (50mm, 100mm, 200mm, 300mm, and 450mm). In the case of adhesive repairing, repair effect is not obtained at the end of the adhered area; nevertheless the adhered area (length) is defined repair area (length) in this study for convenience.

Table 1 shows the details of steel plate, repair plate, and adhesive. In the case of CFRP repair, the product of the cross-sectional area and Young's modulus is assured in adhered four layers per side[2)].

3 RESULTS

3.1 Results of Method to Adhere Steel Plates

Figure 3 shows the maximum load of each specimen before the effect of repair plates is lost. It clarifies that the maximum load increases when the adhesive length is longer. S-5 specimen having 450mm in repair length is adhered to all of damaged area and a part of undamaged area; therefore, the strength of S-5 specimen has increased higher than that of undamaged status. On the other hand, in both of the specimens having 200mm and 300mm repair length, these strength have increased up to 98-99% compared with that of the undamaged status.

Figure 4 shows the strain of the base steel when the specimens was subjected by the loading 300kN; whereas, 300kN is the load that base steel without repairing will yield partially. At the 219mm position, which is the minimum cross-sectional area position, it can be seen that the strain of all the specimens except for N-1 and S-1 is almost equal. It is known that there is no stress concentration in cross section having certain distance or more from the end of adhering-plate area[3)].

From Figures 3 and 4, it can be said that it is possible to obtain sufficient partial repair effect if steel plate is adhered in the range of 200mm or more in this case.

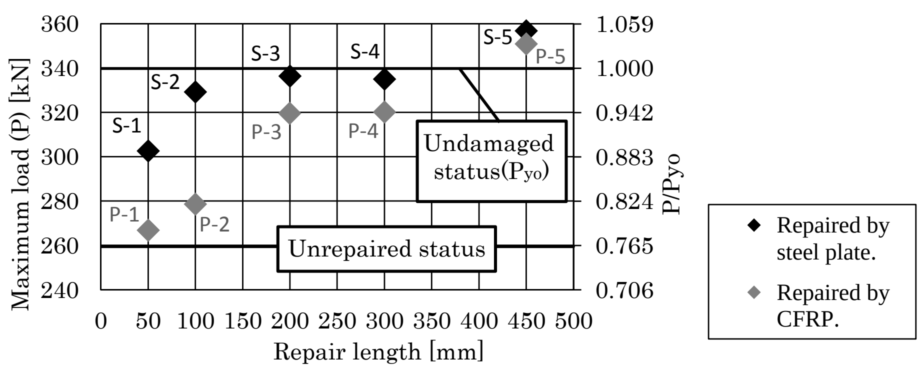

Figure 3. Maximum load.

[2] Nippon Expressway Research Institute Company, Guide to design and construct repairing of steel structures using CFRP, 2013.
[3] Aoki, Y., Banno, R., Ishikawa, T., Kawano, H., and Adachi, Y., Bending behavior of thickness-reduced steel member repaired with patch plate on one side, Japanese Society of Civil Engineers, 59A, 647-656, 2013.

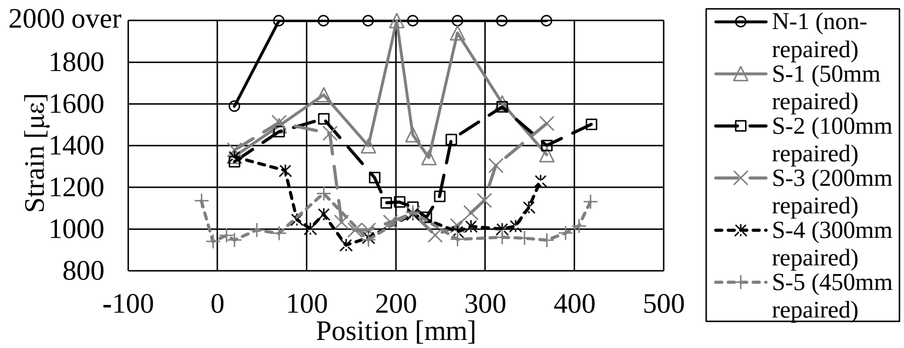

Figure 4. Strain of base steel (Repaired by steel plate).

3.2 Result of Method to Adhere CFRP

From figure 3, the strength of P-5 specimen having 450mm in repair length has increased higher than that of undamaged status, similar to the specimen adhered the same length of steel plate. On the other hand, both of the strengths of the specimens having 200mm and 300mm repair length have increased up to 94% that of the undamaged status. Figure 5 shows the strain of the base steel loaded 300kN. It is clearly that the strain of all the specimens except for N-1, P-1, and P-2 is almost equal at the 219mm position.

From Figures 3 and 5, it can be said that it is also possible to obtain sufficient strength repair effect if CFRP is adhered in the range of 200mm or more in this case.

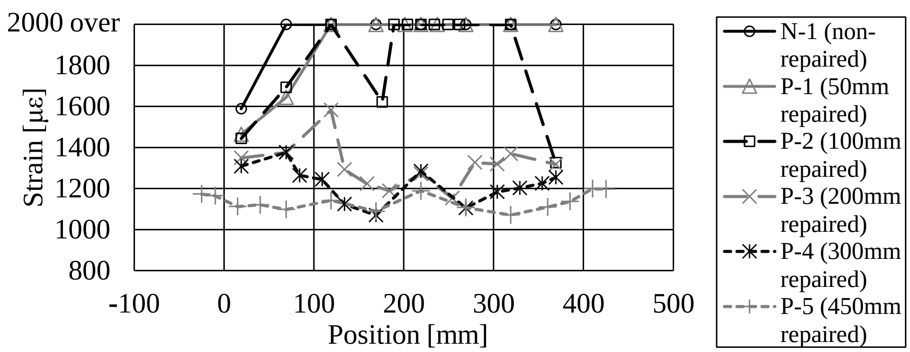

Figure 5. Strain of base steel.

4 EXPERIMENT TO CHANGE SURFACE PREPARATION GRADE

In the following section, we consider the effects of remained rust. Based on the results of the previous section, repair length is kept constant at 200mm in this section. The amount of reduced thickness is the same as previous specimens (Figures 1 and 2). Surface preparation grade is defined by the eq. (1).

$$P_{sp} = \frac{A_0 - A_c}{A_0} \times 100 \quad (1)$$

P_{sp} : Surface preparation grade [%]. A_0 : Adhere area [mm^2]. A_c : corroded area in adhere area [mm^2]

Figure 6 shows the example of artificial simulated rust made of tape paper. Both methods (steel plate and CFRP) were implemented by four types of surface preparation grade.

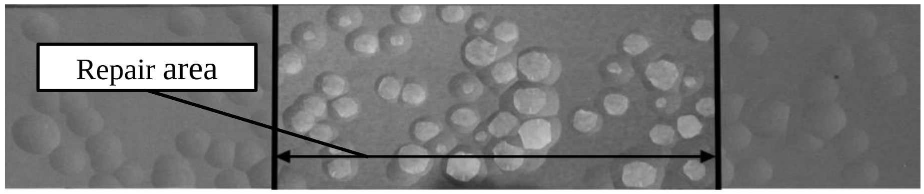

Figure 6. Artificial simulated rust.

5 RESULTS

5.1 Results of Method to Adhere Steel Plates

Figure 7 shows the maximum load of each specimen before repair plate was peeled off. For S-3 specimen, the surface preparation grade of which is 100%, its strength withstood up to 99% of the load compared with undamaged specimen yielding. However, other specimens repaired by steel plate withstood up to only 88-96% of the load compared with undamaged specimen yielding. Thus, strength recovery effect is obviously reduced by the influence of the remained rust.

Figure 8 shows the strain of the base steel loaded 300kN. S-3-1 specimen's strain is larger than that of other specimens, even though S-3-2,3,4 and S-3 specimens do not have big difference. Thus, it is suggested that strength recovery effect will be maintained unless steel plate is peeled off.

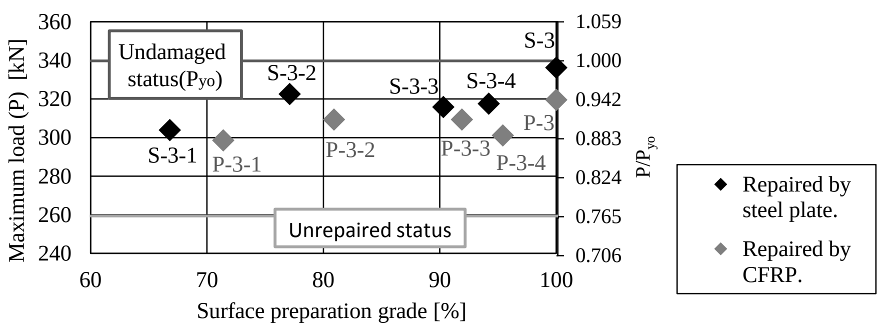

Figure 7. Maximum load.

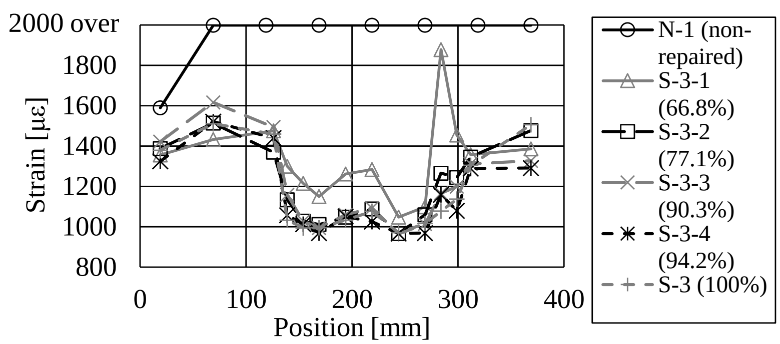

Figure 8. Strain of base steel (Repaired by steel plate).

5.2 Result of Method to Adhere CFRP

According to Figure 7, similar to specimens using adhered steel plate, P-3-1,2,3,4 specimens only withstand up to 86-91% of the load compared with undamaged specimen yielding. On the other hand, P-3 specimen withstands up to 94%.

Figure 9 shows the strain of the base steel loaded 300kN. P-3-1 specimen had already be peeled off CFRP, as a result it had no repair effect when 300kN was loaded to that. However, other specimens did not have big difference. Thus, it is suggested that strength recovery effect will be also maintained unless CFRP is peeled off.

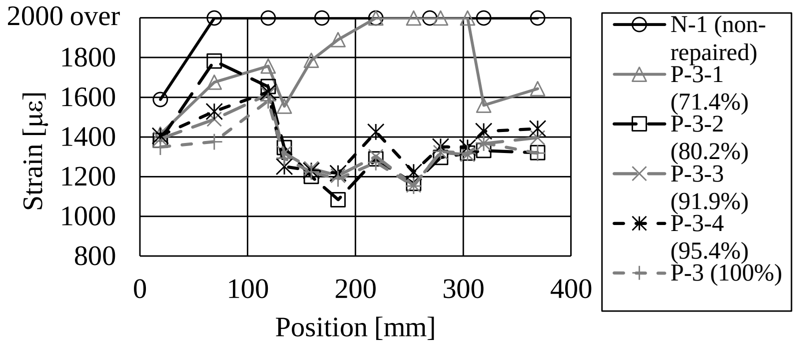

Figure 9. Strain of base steel (Repaired by CFRP).

6 CONCLUSION

1. The ultimate load increased when the repair length was longer. However, specimens having 200mm or 300mm repair length had the almost same repair effect each other. Furthermore, the strain of the base steel in the specimens loaded 300kN having 200-450mm repair length were also nearly equal each other. Thus, the reduction of strain of the base steel and the effect of the partial strength recovery can be expected if there are 200mm or more repair length.

2. The maximum load before the repair effect were lost decreased when the surface preparation grade was worse. The repair effect decreased 9 points in the specimens using adhered steel plate, and decreased 7 points in the specimens using adhered CFRP. Even though, unless steel plate or CFRP peeled off, the repair effect did not decreased.

3. It would be the future tasks to establish a new maintenance manual by clarifying the effect of repair area and remaining rust on repair effect. For that purpose, it is needed to conduct further investigation.

References

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Nippon Expressway Research Institute Company, *Guide to design and construct repairing of steel structures using CFRP*, 2013.