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RENOVATION OF CORRODED GIRDER END IN PLATE GIRDER BRIDGE WITH RESIN AND REBARS

HIROSHI OGAMI[1], KATASHI FUJII[1], TOMOYUKI YAMADA[2], and HATSUMI IWASAKI[3]

[1]*Hiroshima University, Hiroshima, Japan*
[2]*IHI Construction Service Coporation, Tokyo, Japan*
[3]*IHI Corporation, Tokyo, Japan*

There have been found a lot of corrosion damages recently in steel bridges aged for fifty or more years, especially in plate girder bridge, we can notice serious damages at girder ends involving supports. Then, the girder-end should be repaired adequately against the thickness loss caused by corrosion. This paper presents a repair method for corrosion damage at girder-end, in which rebars and shear connectors are fixed to the corroded member using with resin. In order to investigate the effect of recovered strength, we conducted axial compressive tests for six cruciform columns. One of the six specimens has no corrosion damage. The other five have the same unevenness imitated a corroded surface which is made artificially by drilling, for the purpose of grasping the quantitative effect by the repair method. During the test, ultimate strength and post buckling behavior of the cruciform columns are also investigated as well as recover effects. It is concluded from test results that this repair method can enhance the axial remaining strength sufficiently, beyond the ultimate strength of the non-corroded specimen because the buckling length become shorter by repaired resin thickness than the column length which is equal to the buckling length in the non-corroded case.

Keywords: Corrosion, Repair, Steel Bridge, Buckling.

1 INTRODUCTION

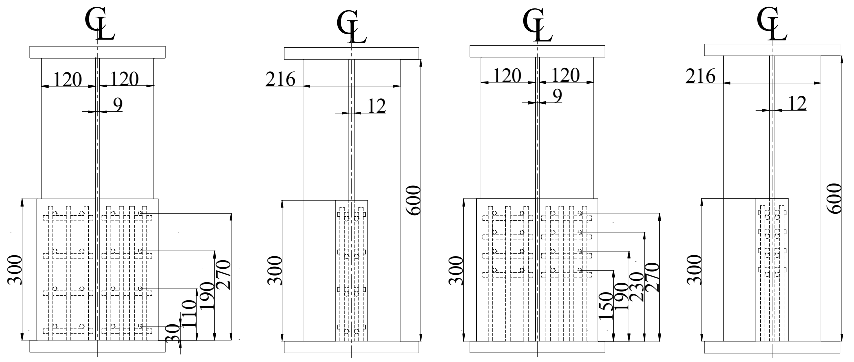
In the plate girder end of steel bridge, serious damage of corrosion appear at the lower part of vertical stiffeners and web plates very often, which is due to water leakage from the expansion joint1). Such damages must to be repaired appropriately because there is risk that leads to decrease the strength of the steel girder. But it is difficult to repair with patch plates or CFRP, which are adopted in many construction cases, because girder-end is usually complicated details with cross beam and bracing members etc. In recent years, repair method using stud and rebars which are enveloped with a resin has been proposed in place of the repair method using patch plates2). Then its applicability has been confirmed for the member subjected to axial tensile force in previous research. However, it has not yet been clear about the applicability in the case of the compressive member such like girder-end which is usually designed as a cruciform column consisted of vertical stiffeners and a part of girder-web. Then in this study, we made specimens of cruciform columns with corroded surfaces which are made artificially by drilling due to “surface generation method” developed in our laboratory[3)]. And after repairing corroded region, axial compression tests were conducted changing the repair condition. Then we investigated ultimate behavior and strength to provide the basic data towards the establishment of design methodologies.

2 SPECIMENS AND LOADING TEST

Specimens for loading test are cruciform column as shown in Figure 1, and each specimen type is shown in Table 1. For the specimen, thickness of the stiffener is 12mm and the web is 9mm. The resin thickness and the location of studs were changed as parameters. As indicated in Table 1, resin thickness is two types of 25mm and 30mm, and the difference between Type A and Type B is the different location of arranged studs, as Figure 1.

Before loading test, corroded area is repaired by covering with resin after rebars are fixed to the studs. At that time, the lower end of rebars gets in touch with the bottom flange, in order to transmit the axial force of the rebar to the flange. Here, thickness contour and cross section average thickness distribution are shown in Figure 2 and Figure 3. Corrosion range is 200mm. Corroded surface was made as increased corrosion amount as lower. This is with reference to the prone corrosion situation in actual steel bridge. Moreover, corroded surface are different in all surfaces of stiffeners. And this corroded surface is almost the same in all specimens, it is possible to thereby quantitatively determine the effects of various repair conditions.

The purpose of design of rebar and stud is to make up for the strength reduction due to the cross-sectional loss at the minimum cross-section area position of each stiffener by rebars and studs. Specifically, as shown in equation (1), to determine the diameter and number of rebar as the rebars can carry the axial force caused by the cross-sectional lack. Also studs are determined as shown in equation (2), as the shear stress of studs can withstand axial force acting on rebars. In these equations, σ_y and τ_y are yield normal and shear stress, respectively, and P is yield strength of the no-corroded steel plate, A_{min} is the minimum cross sectional area of the stiffener.



Type A

Type B

Figure 1. Specimens.

$$\sigma_y A_R \geq P - A_{min}\,\sigma_y \qquad (1)$$

$$\tau_y A_d \geq P - A_{min}\,\sigma_y \qquad (2)$$

No corrosion

Table1. Type of the specimens.

Specimen No.	corrosion	Stud placement Type	Resin thickness (mm)
1	—	—	—
2	○	—	—
3	○	Type A	25
4	○	Type A	30
5	○	Type B	25
6	○	Type B	30

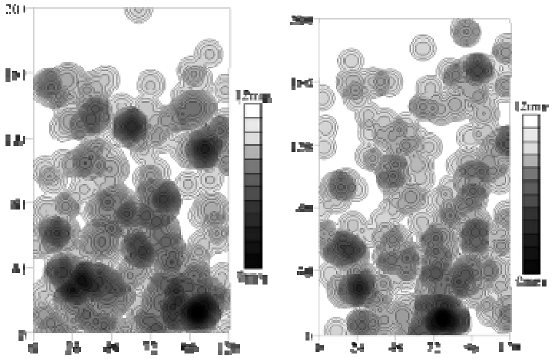


Figure 2. Thickness contour (Left:Pattern 1, Right:pattern 2).

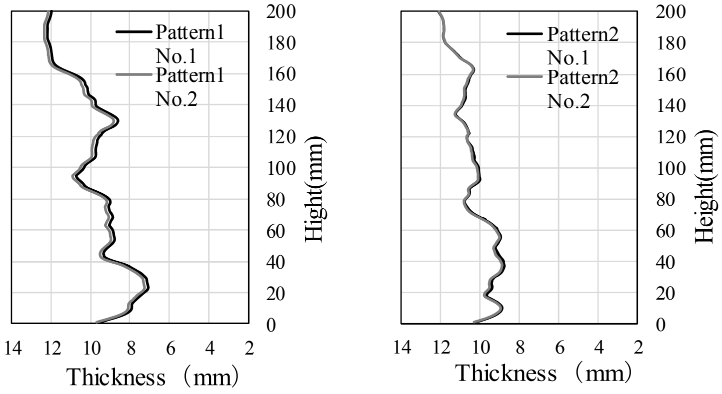


Figure 3. Average thickness distribution of cross section.

3 RESULT

3.1 Failure Mode and Strength

The failure mode of specimens is shown in Figure 4. Continuing with the loading for a while after the maximum load, torsional buckling occurs in all specimens. In the non-corroded specimen, it has become common buckling mode that maximum deflection occurs in the middle of the buckling length. In the non-repaired specimen, buckling occurs in the lower region having corrosion. From this fact, we are able to confirm that the buckling position is different due to the cross-sectional loss by corrosion. Also, since the buckling occurs near the lower end, remarkable deflection did not occur. In the repaired specimens, regardless of the resin thickness and the location of studs, torsional buckling occurred at the upper region without rebars and resin.

Then, Load-Displacement curve is shown in Figure 5. The strength has dropped to 85% of the non-corroded specimen due to corrosion. And, by applying this repair method, it was recovered more than 100% strength of non-corroded specimen. In addition, throughout the all repaired specimens, the difference in the resin thickness and the location of studs do not affect the performance of recovery is confirmed, because very little difference to the failure mode and the strength appeared. Strength recovery effect of all specimens affected by the failure mode.

Non-corroded Non-repaired Repaired

Figure 4. Failure mode.

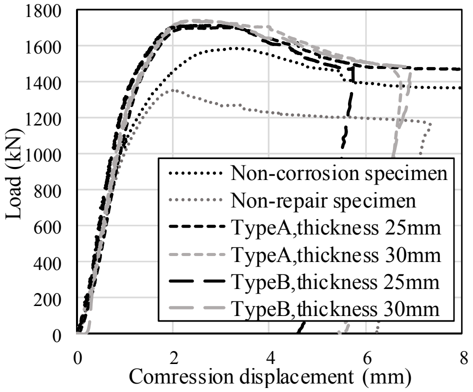


Figure 5. Load-Displacement.

3.2 Strain

The compressive strain in the height direction of the stiffener in the non-repaired specimen is shown in Figure 6. The compressive strain at 22mm height that is minimum cross-sectional area has increased remarkably from initial loading in the non-repaired specimen. It can be seen that the lower part that has terrible corrosion become fragile part, since it is also about 1000～2000με even at the maximum loading in other parts. But, as shown in Figure 7 the compressive strain in minimum cross-sectional area was able to greatly reduce by applying this repair method. And it is understood that there is no much change in the bending strain of the rebar and the resin in comparing initial loading and after yield of the base metal, from bending strain of the rebar, resin and web that is shown in Figure 8. Furthermore, since the bending strain of the repair part is smaller than it of upper part at the maximum loading, it was confirmed that no buckling occurs in the repair part. In other words, it is able to eliminate the fragile part by repair.

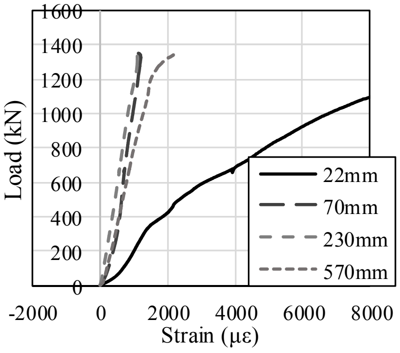


Figure 6. Compressive strain of Non-repaired specimen. (left)

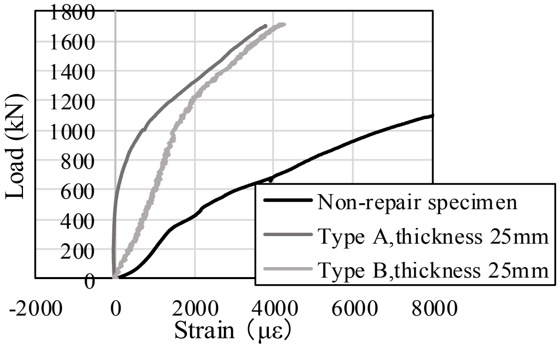
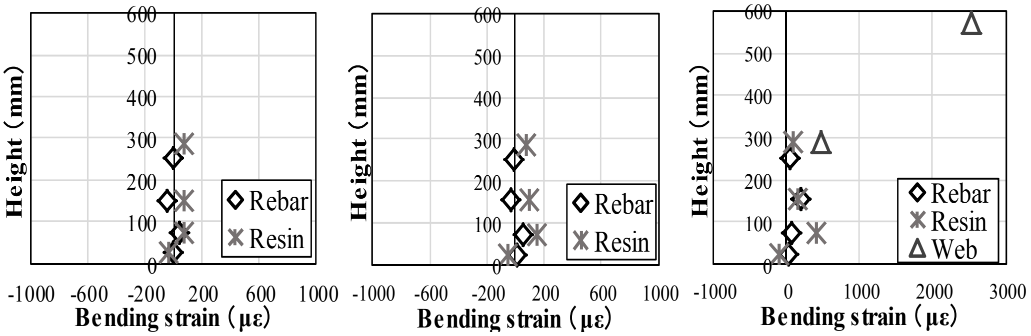


Figure 7. Compressive strain in minimum cross-sectional area. (right)



Initial loading After yield Maximum loading

Figure 8. Bending Strain.

4 CONCLUSION

The strength recovery effect of all repaired specimens could be confirmed. Therefore, it was found that this repair method is also applicable to the member under compressive force. Moreover, it is able to prevent the buckling of corroded lower part by applying this repair method. In addition, it was confirmed that placement of studs does not affect the failure mode and the strength so much. From this result, we would be able to select stud placement Type B because of easiness to drive studs.

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