CFRP Repair Method for Corroded Steel Girder Ends

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Summary

Loss of cross section owing to corrosion is a primary factor in the deterioration of steel bridges. Therefore, carbon fiber-reinforced plastic (CFRP) has attracted attention as a material for repairing and reinforcing steel bridges because of its light weight, high strength, and superior durability. Although many studies have been published relating to this topic, previous studies have primarily focused on the application of CFRP to axial or bending members. However, most of the corrosion is found on the webs or columns at the ends of the main girders. Few investigations have examined repairing corroded webs or columns using CFRP. In this research, a shear buckling test for steel girders and a uniaxial compression test for cruciform columns are conducted to develop a repair method for corroded steel girder ends using CFRP sheets. In this method, low elastic putty layers are inserted between steel and CFRP sheets to improve the performance of out-of-plane deformation.

Keywords: carbon fiber-reinforced plastic; steel bridge; corrosion; buckling; repair.

1. Introduction

In Japan, most of the deterioration of steel structures stems from corrosion. In particular, steel girders are corroded at the ends owing to water leakage from expansion joints. Additionally, deicing salts used in winter worsen this situation. The usual repair work for such damage includes replacing corroded members with new ones or attaching new steel plates onto the corroded part using bolts or welding. However, these repairs lack workability because heavy machinery and welding devices are required, regardless of the scale. As a result, repair works have not progressed, despite the increasing number of corroded locations. This has become an issue. Therefore, a simple and effective repair method for corroded steel girder ends is urgently needed.

To overcome this problem, we focused on fiber-reinforced polymers as repair materials for corroded steel girder ends. Among them, carbon fiber-reinforced polymer (CFRP) is particularly promising owing to its light weight and superior elasticity, strength, and durability. Repairs to seismic retrofit concrete structures using CFRP have been extensive in Japan. However, applications of CFRP to steel structures are comparatively rare, although CFRP has been applied to flanges in steel girder bridges and chord members in steel truss bridges. In general, these members are subjected to normal stress. However, corrosion in steel bridges primarily occurs at webs or vertical stiffeners near supports. With these members, local buckling is of concern, yet there are few studies on the application of CFRP to these members. Ref. [1] presents the test results on CFRP plate-stiffened light steel beams under end-bearing loads. These tests revealed that CFRP strengthening significantly increases the web-buckling capacity. However, it was not known whether CFRP-stiffened beams reached the maximum load owing to debonding. Moreover, this research does not address shear buckling or the repair of corroded steel. Therefore, this study focuses on the applicability of CFRP in repairing corroded webs and vertical stiffeners at the ends of steel girders.

2. Repair Method Using CFRP Sheet

When corroded vertical stiffeners or webs are in an ultimate state, local or shear buckling might occur under compression or shear. Thus far, it has not been reported whether CFRP bonded on these members can adapt to large deformations and recover the initial performance of the members. Therefore, we studied the constitution of the adhesion layer that will prevent the delamination of CFRP caused by buckling. Our previous study confirmed that inserting polyurea putty, which has a low elastic modulus (55–75 MPa) and high elongation (300–500%), between the steel plate and CFRP sheet can help prevent delamination under large deformations. In this study, it is difficult to acquire material properties from non-tensile tests because elongation at the break is excessively high. A high modulus carbon fiber sheet, with Young's modulus of 640 GPa, displayed the best repair efficiency among the various FRP sheets tested. Therefore, we propose a repair method for corroded vertical stiffeners and webs at steel girder ends using CFRP sheets. In the following sections, we will report on the practical design method and the results of experiments conducted to confirm its validity.

3. Conclusions

The objective of this study was to establish a repair method using CFRP sheets for corroded steel girder ends that have reduced load-carrying capacities in compression and shear. (1) CFRP sheets were adhesively bonded on corroded vertical stiffeners and/or webs near supports by using a putty layer with low elastic modulus. This putty layer prevents delamination of CFRP sheets when large deformations are induced by buckling. (2) First, we conducted uniaxial compression tests of girders to confirm the applicability of the proposed method to corroded supports that have reduced load-carrying capacity in compression. The thickness of the bottom of the girders was reduced to simulate corrosion. Results of the experiments revealed that initial performance can be recovered by adhesively bonding CFRP sheets. (3) Next, shear buckling tests were conducted to confirm the applicability of the proposed method to corroded webs near supports with reduced load-carrying capacity under shear. Test girders were full-scale models and corrosion was simulated by creating a through-hole, reflecting the extreme condition of the girders. Results of the experiments showed that even when severing corrosion created a through-hole on the end web panels, load-carrying capacity under shear can be recovered by using the proposed method to appropriately bond CFRP sheets on the corroded webs.

References

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