EXPERIMENTAL STUDY ON REPAIR METHOD USING CFRP FOR CORRODED GUSSET PLATE CONNECTION IN TRUSS BRIDGE

Nagaoka Univ. of Tech.	Student Member	○ Ngoc Vinh PHAM
Nagaoka Univ. of Tech.	Regular Member	Takeshi MIYASHITA
Institute of Technologists	Regular Member	Kazuo OHGAKI
Nagano National College of Tech.	Regular Member	Yusuke OKUYAMA
Nippon Steel & Sumikin Material Co.	Regular Member	A. KOBAYASHI and Y. HIDEKUMA
Nippon Expressway Research Institue Co.	Regular Member	T. HIROSE and M. HATTORI

1. INTRODUCTION

Recently, damaged steel truss bridges due to corrosion have become seriously problematic in the world. Typical case is the collapse of steel truss bridge I-35W due to corrosion and other main causes in the USA in 2007. Moreover, a survey conducted by Highway Administration Division of NEXCO reported that potential corrosion locations are commonly found on gusset plate connection members because of their complex shapes, debris and water accumulation as shown in Fig. 1. The attachment of stiffening plate and member replacement are some of the traditional methods often applied to repair corroded structures. However, these repair works lack in workability because heavy machinery and welding facilities. Therefore, a simple and effective repair method for the corroded gusset plate connection is urgently needed. To counteract this problem, this study focuses on carbon fiber reinforced polymers (CFRP) as repair material for the corroded gusset plate connection.

Figure 1. Commonly corroded member of truss bridge

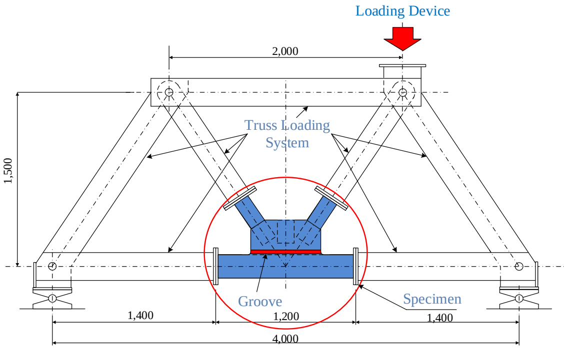

Figure 2. Specimen shape

2. EXPERIMENTAL OVERVIEW

2.1 Specimen shape

The loading experiment of the specimens of gusset plate connection was carried out by the truss loading system as shown in Fig. 2, with a model of approximately 1/2 size of real bridge. And, cross-section loss due to the corrosion were expressed by cutting a groove (in the following, be named groove) on the gusset plate. The truss loading system were connected to the specimen by using the bolts. Also, the specimen was changed after finishing the experiment, and keep the truss loading system for the next experiment.

2.2 Material property

The mechanical properties of the employed CFRP and the steel are shown in Table 1. The elastic modulus of this CFRP was 3.2 times higher than that of the steel. Therefore, one layer of CFRP corresponded to the steel thickness of 0.4576 mm.

Table 1: Material property

	CFRP (FTS-C8-30)	Steel (SS400)
Elastic modulus (GPa)	640	200
Tensile Strength (MPa)	2430	
Yield Stress (MPa)		317
Design thickness (mm)	0.143	

2.3 Experimental parameter

The experimental parameters in this study are shown in Table 2. The degree of corrosion was assumed about to 1/2 and 3/4 of the gusset plate thickness. In each case, their load capacity were tested when repaired and not repaired. The direction of CFRP is interwoven with an angle of ±45 degrees, with two forms, respectively as one-sided and two-sided bonding as shown Fig. 3. And, the amount of bonded CFRP for each direction is determined with a larger tensile rigidity than the rigidity of the cross-sectional loss. The total number of test specimen is 7.

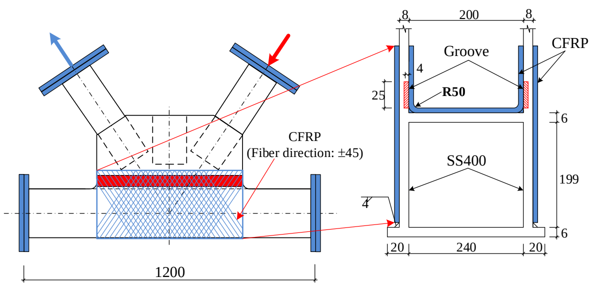

Figure 3. CFRP bonding method

3. RESULT AND DISCUSSION

3.1 Max-Load and final condition

The Max-Load and the final condition of the specimens were shown as Table 3. The load value of N, S, S1, S2 series may continue to increase; however, the temporary max-load has reached the capacity of the experimental equipment

Keywords: Corrosion, Truss Bridge, Gusset Plate Connection, Repair Method, CFRP
Contact address: 1603-1, Kamitomioka Nagaoka, Niigata 940-2188, JAPAN

(3000 kN). In the case of the L series with the degree of large corrosion, its loading capacity has reduced significantly compared to the case without corrosion. However, by the proposed repair method, their loading capacity has increased significantly, with the improvement rate of 55.5% and 74.7% respectively. Besides, with the same amount of CFRP, the two-sided bonding method has improved the loading capacity of the L by 13% compared to the one-sided bonding method.

Table 2. Experimental parameter

No.	Specimen	Corrosion level	CFRP bonding method	Number of CFRP (layer)
1	N	Without corrosion	No repair	
2	S	Small corrosion 25mm width X 1/2 of thickness	No repair	
3	S1		One-sided only	9 outer (each direction)
4	S2		Two-sided	4 inner + 5 outer (each direction)
5	L	Large corrosion 50mm width X 3/4 of thickness	No repair	
6	L1		One-sided only	13 outer (each direction)
7	L2		Two-sided	6 inner + 7 outer (each direction)

3.2 Load-displacement relation

The relation between load and vertical displacement at the lowest central point of specimens are shown in Fig. 4. The initial stiffness of the L reduced significantly due to the large cross-section loss in the gusset plate. However, by the repair method using CFRP, their initial stiffness has been recovered as the N without cross-section loss.

Table 3. Max-Load and final condition

	N	S	S1	S2	L	L1	L2
Maximum Load (kN)	3000	3000	3000	3000	1430	2223	2498
Max-Load Improvement Rate (%	–	–	–	–	–	55.5	74.7
Specimen After Testing							
Deformation	–	Local deformation at the gusset plate	Local deformation at the gusset plate	–	Large deformation at the groove section	Large deformation at the groove section	Large deformation at the groove section

3.3 Load-Von Mises stress relation

The relation between load and Von Mises stress calculated from the experimental data are shown in Fig. 5. In the cases of using the one-sided bonding method, the groove section has been plasticized completely. This is understood that the eccentric moment due to the one-sided bonding CFRP has increased the stress at the groove section significantly. However, with the efficiency of reducing the eccentric moment of the two-sided bonding method; the stress at the groove of the S2 and L2 has decreased sharply, and distributed nearly the same as the N without cross-section loss.

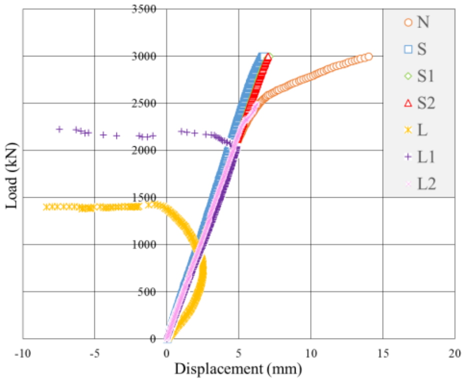

Figure 4. Load-displacement curve

4. CONCLUSION

The results obtained from this study are summarized as follows.

- The reduction of load carrying capacity of gusset plate connection, due to the gusset plate corrosion, was clarified.
- The proposed repair method using CFRP was able to recover the initial stiffness of the corroded gusset plate connection, and increase their loading capacity.
- By the two-sided bonding method, the stress distribution at the corrosion section has been recovered to nearly the same as the case without corrosion.

REFERENCES

Dai Wakabayashi, Takeshi Miyashita, Yusuke Okuyama, Yuya Hidekuma: REPAIR METHOD USING CFRP FOR CORRODED STEEL GIRDER ENDS, Fourth Asia-Pacific Conference on FRP in Structures (APFIS 2013), Australia.

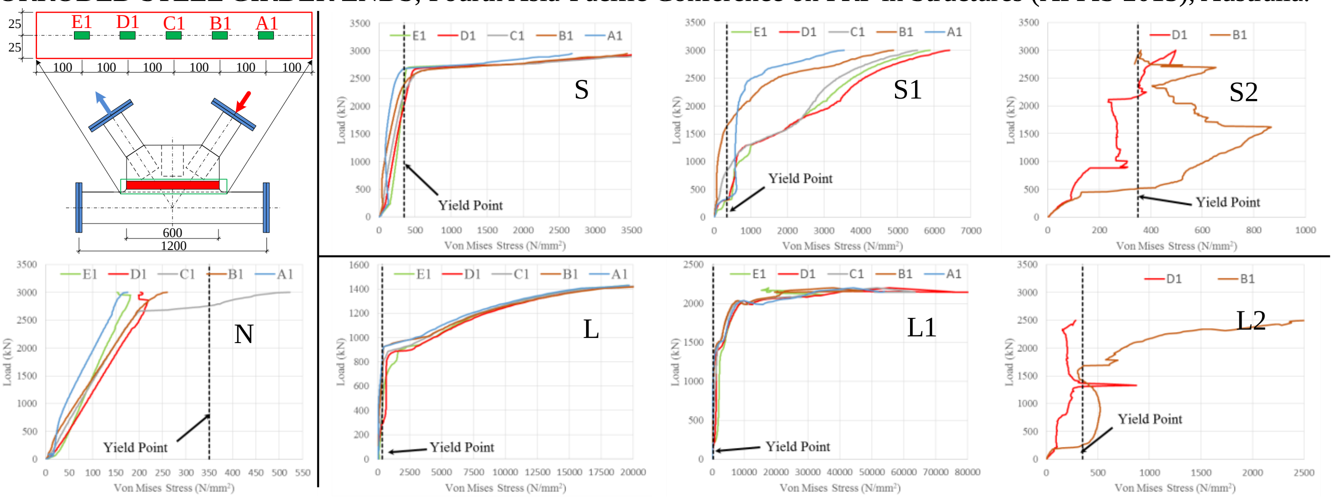

Figure 5. Load – Von Mises stress