EFFECT EVALUATION OF REPAIRING METHOD USING CFRP SHEET FOR STEEL GIRDER END

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1. INTRODUCTION

In recent years, a new method to repair corroded steel girders ends using CFRP (Carbon Fiber Reinforced Polymer) sheets has been proposed. This new method has been already included on the Nippon Expressway Company Standards Manual.

Even though many laboratory tests have been performed, and the increase on ultimate strength and a decreased on stress level in members where CFRP sheets were bonded have been already verified, there are restrictions in the laboratory test that impedes the examination of certain corrosion cases. Additionally, since this is a new method, there are only a few cases where CFRP was used to repair steel bridges, and the data about its performance on real bridges is still scarce. Therefore, one of the objectives of this study is the evaluation of the CFRP repair method performance on a corroded steel girder end by verifying the strain reduction on this section.

In addition, the correction coefficient (C_n) used during the design procedure is examined. This correction coefficient considers the delay in stress transfer between the steel plate and CFRP sheet due to the insertion of a high-elongation putty layer.

2. BRIDGE OF STUDY

During the inspection of a steel bridge in service severe corrosion damages were found in the vicinity of two supports. After several evaluations, it was decided to repair the bridge by using CFRP sheets.

The above mentioned bridge is a steel bridge with 4 I-shaped girders and a RC deck. It is a 72.0 m long-bridge, and it possesses two spans of 36.0 m. It was completed and opened to traffic in 1973 (See Figure 1).

Figure 1. Bridge of Study.

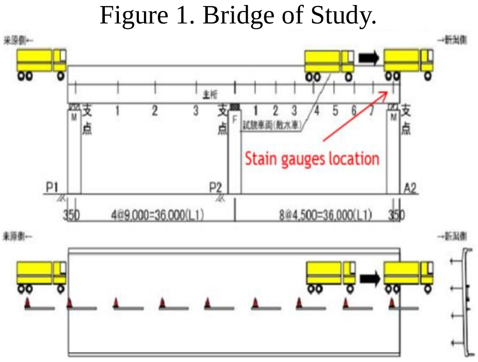

Figure 3. Loading Position (Static Loading Test).

3. ON-SITE MEASUREMENTS & STRUCTURAL IDENTIFICATION

Before and after applying the CFRP repair method, full-scale static and dynamic tests were conducted in the bridge. The main purpose of these tests is to grasp the behavior of the damaged and repaired bridge, and based on these results, to evaluate the strengthening effect by CFRP repair method. In these tests, the corresponding relative strain variation from the measured strain response before and after bonding CFRP sheets was determined (See Figure 2 & 3). It should be noticed that in some sections, the strain gauges were attached above the CFRP sheets (lower section of the after repair case).

In addition, vibration measurements for structural identification were also conducted.

4. FINITE ELEMENT MODEL

A three-dimensional linear elastic Finite Element Model of the bridge of study was created. The geometry and material properties of the original model were modeled based on the design drawings (See Figure 4 & Table 1). In addition, a model which considers corrosion damages, and other model which considers the CFRP repair were also created. CFRP elements were modeled using laminate plate elements (stack of individual sheets oriented at certain angle from the principal material directions).

The model is updated based on the dynamic response of the bridge measured on-site. The spring coefficient stiffness is modified until finding a good correlation between the natural frequency measured on-site and the one obtained from the Finite Element Model.

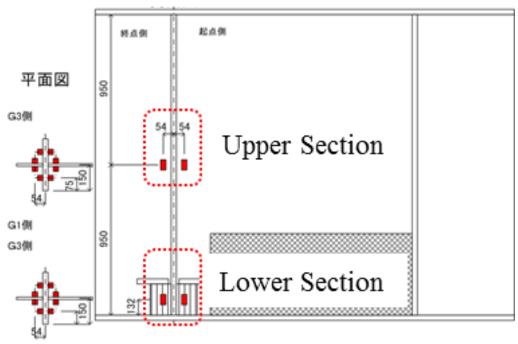

Figure 2. Strain Gauge Location at G2.

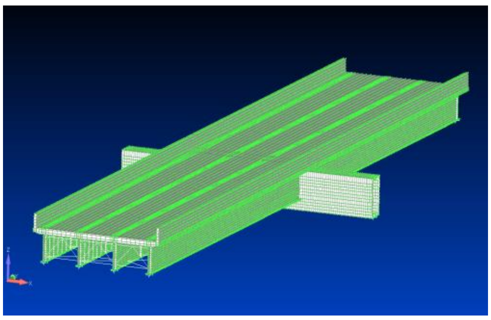

Figure 4. Finite Element Model.

Table 1. Finite Element Model Properties.

Member	Element Type	Material	Elastic Modulus (MPa)	Poisson's Ratio	Density (kg/m^3)
Main Girders	Plate	Steel	200,000	0.30	7,860
Box Beam	Plate	Steel	200,000	0.30	7,860
Stiffeners	Plate	Steel	200,000	0.30	7,860
Braces	Beam	Steel	200,000	0.30	7,860
Slab	Solid	Concrete	31,000	0.15	2,400
Pavement	Solid	Asphalt	200	0.40	2,250
CFRP Sheets	Laminate Plate	CFRP	640,000	0.31	2,100

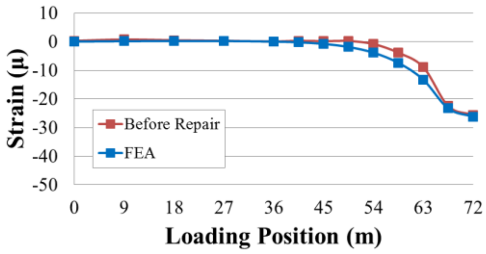

Figure 5. Upper Section Before Repair.

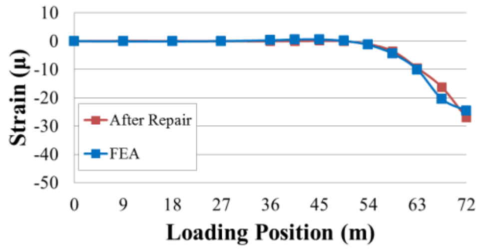

Figure 6. Upper Section After Repair.

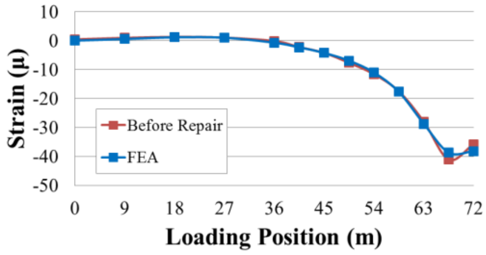

Figure 7. Lower Section Before Repair.

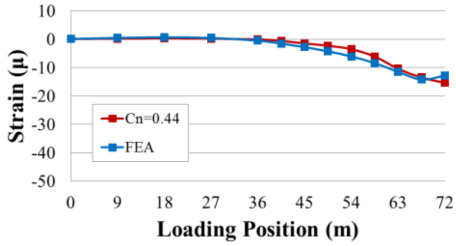

Figure 8. Lower Section After Repair.

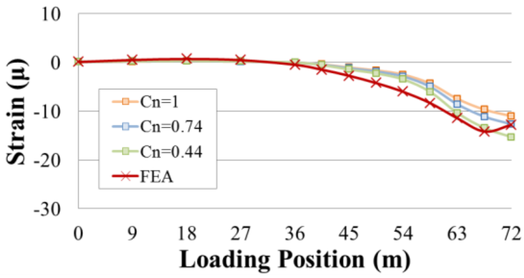

Figure 9. Strain Distribution after Repair for different C_n (Lower Section).

5. RESULTS

The obtained results can be summarized as:

A) Strain Distribution (Upper Section): Because the section was out from the CFRP bonding area, no big difference in the strain level before and after repair is observed neither in the on-site measurements nor FE analysis results (See Figure 5 & 6).

B) Strain Distribution (Lower Section): Since the strain gauges were attached above the CFRP sheets (after repair), it was necessary to consider a C_n. Firstly, the steel strain reduction was calculated considering the *Cn* used during the design procedure, this is 0.74. However, comparing this strain distribution with the one obtained from FE analysis, it was found that slightly bigger strains were obtained from the on-site measurements. A different value of *Cn* (=0.44) considering the development length (distance from corrosion area to the edge of the outermost CFRP sheet) and shift amount (distance between the ends of each carbon fiber sheet) of all the analyzed sections was calculated. The strain distribution for this value of *Cn* presented a good matching with the FE analysis, founding errors below 10% for cases where the load is near to the support A2, location of the strain gauges (See Figures 7, 8 & 9).

6. CONCLUSIONS

The repair effect on each of the analyzed sections can be summarized as follows:

1. For the upper section, it is thought that no repair effect for this section was obtained (no CFRP sheets were bonded here).
2. For the lower section, it was found that the strain level was reduced in a range from 55~80%, with an averaged value of 69%, when C_n=0.44 was used. The strain reduction was 75% when a C_n =0.74 was considered.

About the correction coefficient, the obtained conclusions can be summarized as:

1. It was confirmed that the C_n is strongly influenced by the development length and shift amount.
2. Since there is no big difference between the strain reduction levels obtained for each coefficient (0.44 & 0.74), it seems like its determination for each section can be omitted and the value described in the design manual can be adopted without significant variation in the results.