NON-DESTRUCTIVE TESTS APPLIED DURING REPAIR WORKS OF THE YODOGAWA BRIDGE

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ABSTRACT

Yodogawa Bridge having a total length of 723.3m is composed by 30 spans, 6 of which are simply supported truss bridges with spans of 32.918m. The bridge, completed in 1926, is located on a heavy traffic route and underwent repair works after being severely damaged during the World War II. Some of the repaired members had complex details whose structural components were not clear and, in some cases, their connections and welds to the original structural members were not visible.

Therefore, a series of studies and site investigations were carried out in one of the spans of the 85 years old bridge with the objective of obtaining information concerning its structural health conditions. During inspections carried out in the former year, a number of internal flaws and defects were found in members repaired in the past. The present study reports on the additional non-destructive tests carried out on these members to find out details of the internal flaws. X-ray was applied to define the geometric shape of the flaw and evaluate the cross-sectional reduction rate. In order to verify the propagation of the flaws, magnetic particle tests were also carried out. In addition, macro- and microstructure analysis were also carried out to verify details of the flaws.

The application of non-destructive tests provided valuable information on the components and conditions of structural details of members that had been repaired in the past. The obtained information gave means to evaluate the structural health of the bridge and depict a deterioration scenario which will be the base for repair works and maintenance measures to be elaborated in the next step of the project.

Keywords: Crack, non-destructive test, magnetic particle test, macro- microstructure analysis, X-ray.

1. INTRODUCTION

As part of a series of studies to extend the service life of aging long-span bridges (Sakano, 2011), non-destructive tests (NDT) and macro- and microstructure analysis were carried out on a 85 years

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old bridge in order to investigate the conditions of flaws and defects found during inspections of the truss members and floor beams carried out in the former year.

2. OUTLINES OF THE BRIDGE

The Yodogawa Bridge, completed in 1926, is 723.3m long and the central 6 spans are simply supported trusses having span length of 32.918m and a width of 20.8m. The present paper reports on additional investigations carried out on one of the central spans trusses in which repair works had been executed as a result of the former year's researches and investigations.

Figure 1: Yodogawa Bridge.

3. NDT AND MACRO- MICROSTRUCTURE ANALYSIS

3.1. Magnetic Particle Test and Macro- Microstructure Analysis

During inspections carried out in previous years, cracks were found at the lower flange of a transverse beam that had been reinforced in the past. In order to execute retrofit works in the damaged area, cracks and superficial flaws had to be removed so as to install new reinforcement plates.

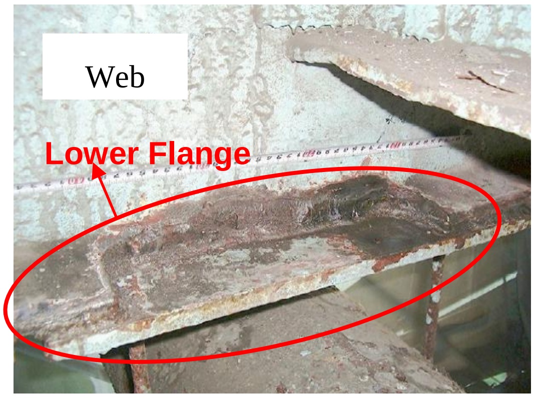


Figure 2: Existing reinforcement plate of transverse beam

Magnetic particle test were applied to check the removal of superficial flaws and macro- and microstructure analysis were carried out to find out the details of the remaining flaws.

3.2. X-Ray

X-Ray test applying digital graphic processing system was applied to find out detailed conditions of butt welds connecting truss members and reinforcement plates that were not visible due to the complex structure of reinforcement works carried out in the past. In addition, an attempt to evaluate the depth of the defect through X-Ray was also made.

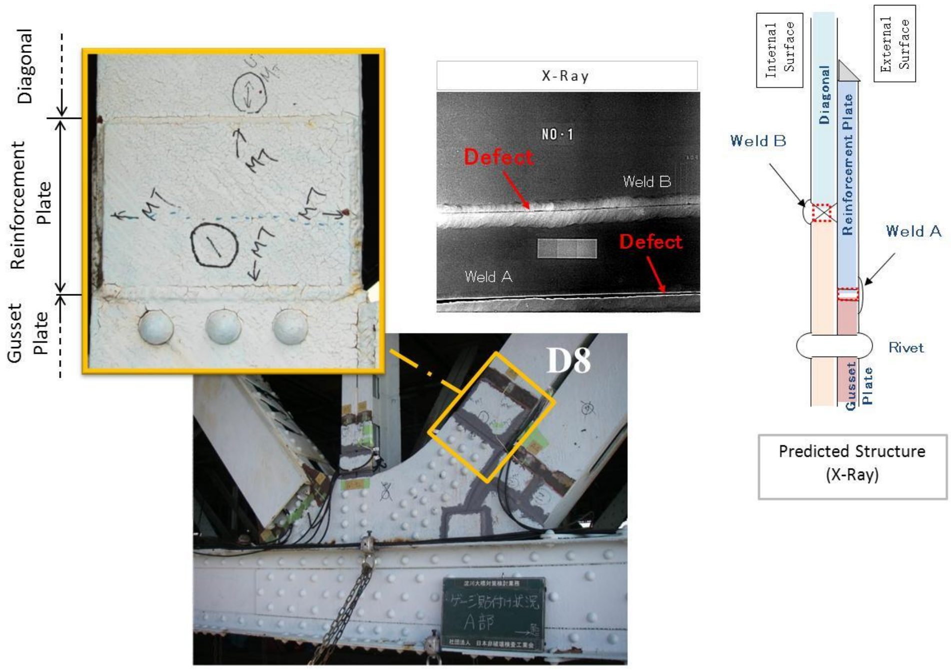


Figure 3: Example of existing reinforcement details in truss members

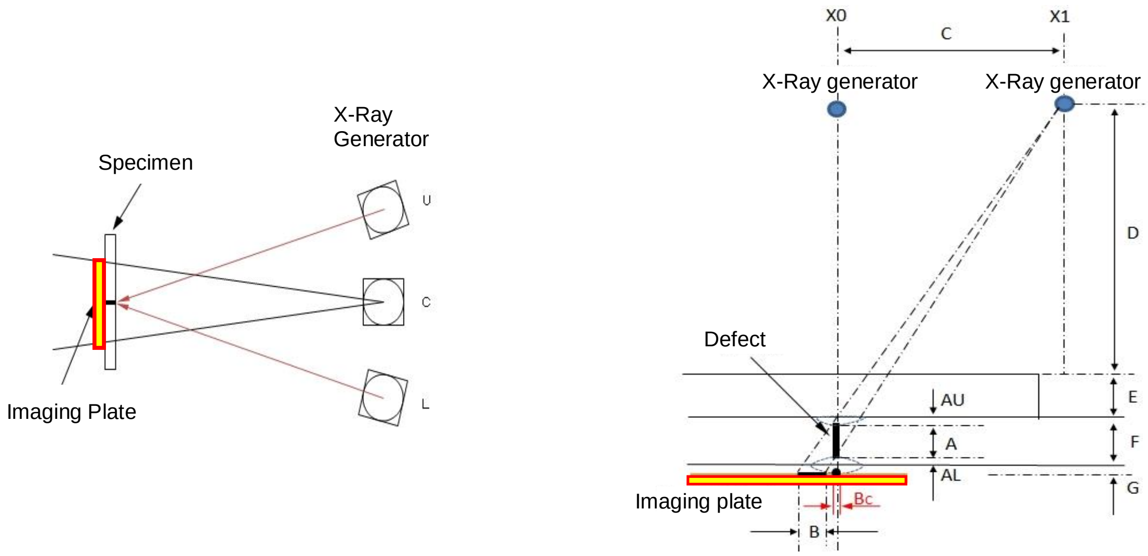


Figure 4: Scheme of the depth evaluation method

Based on Figure 4, the depth of the defect, A, can be calculated according to the following equations, assuming AU and AL to be 3mm.

$$A = \frac{B(D+E+AU)^2}{C(F-AU)+(C-B)(D+E+AU)} \tag{1}$$

$$A = \frac{B(D+E+F-AL)^2}{(D+C)(D+E+F-AL)+C*G+C*AL} \tag{2}$$

$$B = \text{graphically measured value} + 2\% \text{ of thickness} - BC_{(\text{at } X_o)} \tag{3}$$

4. TESTS RESULTS

4.1. Magnetic Particle Test and Macro- Microstructure Analysis

A cracks located at the vicinity of the reinforcement plate of the transverse beam were removed by grinding to a depth of 3mm. However, layers patterns in the steel rolling direction and small cavities could not be completely eliminated, even after grinding to a 5mm depth.

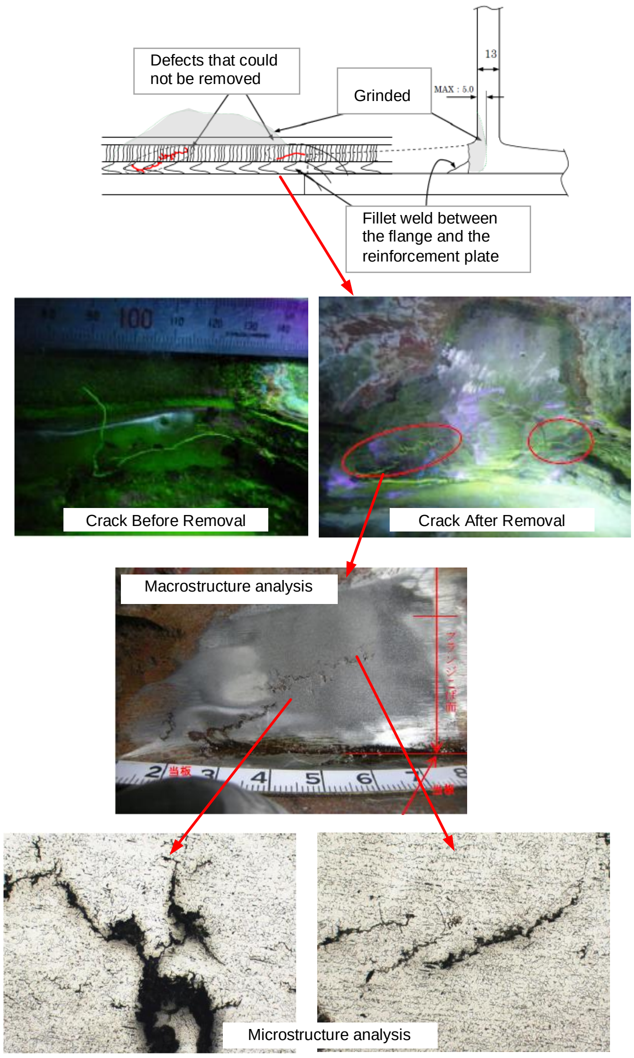


Figure 5: Conditions of the weld at the transverse beam after crack removal

The results of the macro- and microstructure analysis revealed that these flaws were probably originated during the fabrication process of the steel. The magnetic particle test patterns and macro- and microstructure images are shown in Figure 5.

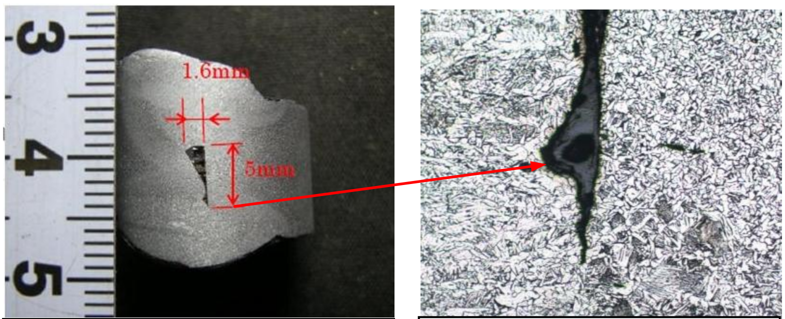
4.2. X-Ray

X-Ray tests were applied to truss members in which reinforcement plates were applied in the past and whose welding connections detailed conditions were still unclear. The depth of the defect was evaluated and the precision of the evaluation was verified by comparing the results to that of direct measurement carried out on defect specimen samples.

Table 1 presents the depth of the defect evaluated by X-Ray test and the results of the measurements carried out directly in the defect samples through macrostructure analysis. The discrepancy between the depths obtained through the 2 methods ranged from -20% to +50%. The edge of the defect was determined more accurately through microstructure analysis.

Table 1: X-Ray evaluation and measured depth

Truss G1 - D8 - Lower -Weld at downstream side		
Side	Measured depth	X-Ray evaluation
A	4.6mm	5.1mm
D	2.9mm	4.3mm
Truss G1 - D8 - Upper -Weld at downstream side		
Side	Measured depth	X-Ray evaluation
A	4.0mm	3.6mm
D	5.0mm	4.0mm
Truss G1 - D7 - Lower -Weld at downstream side		
Side	Measured depth	X-Ray evaluation
A	3.2mm	3.1mm
D	3.1mm	3.4mm



Measurement of defect depth

Defect edge

Figure 5: Macro- microstructure analysis

5. CONCLUSION

During the repair works on the lower flange of the transverse beam it was found that cracks in the vicinity of the welds could not be completely removed and defects in the form of layers remained in the thickness direction. Further investigations through macro- microstructure analysis proved that the defects found in the rolling direction of the steel were probably originated during the fabrication process of the steel.

X-Ray tests proved to be effective in obtaining invisible details of the truss connection parts. Although the depth of the defect evaluated by the X-Ray test compared to that of actual measurements presented a discrepancy that varied from -20% to 50%, the method can be applied to evaluate the cross-sectional reduction rate. In particular, in case of internal flaws, where the application of other non-destructive tests, such as ultrasonic testing is not effective, X-Ray test can be a useful tool to determine the defect geometry.

In both cases, the parallel application of macro- and microstructure analysis provided details that improved the precision of the diagnosis.

The application of non-destructive tests provided valuable information on the components and conditions of structural details of members that had been repaired in the past. These findings gave means to evaluate the structural health of the bridge and depict a deterioration scenario which will provide basis for future repair works and maintenance measures.

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