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CORROSION BEHAVIOR OF FRICTION PLATE SURFACES CONNECTED BY HIGH-STRENGTH BOLTS

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The aim of this study is to examine the corrosion behavior of friction plate surfaces connected by high-strength bolts under severely corrosive environments in steel bridge structures. The corrosion behavior was inspected using corroded specimens cut from a steel girder bridge that collapsed after severe corrosion for 28 years. Visual inspection and measurement of the corrosion thicknesses of the inner surfaces were performed. The arithmetic average roughness was also measured to evaluate the friction coefficient. From these investigations, it may be clear that the aging deterioration of the friction surfaces of joint plates connected by high-strength bolts is has little influence over the slip strength. The details of conducting investigations and their results are presented in this paper.

Keywords: Aging deterioration, Slip strength, Arithmetic roughness, Friction coefficient

1 INTRODUCTION

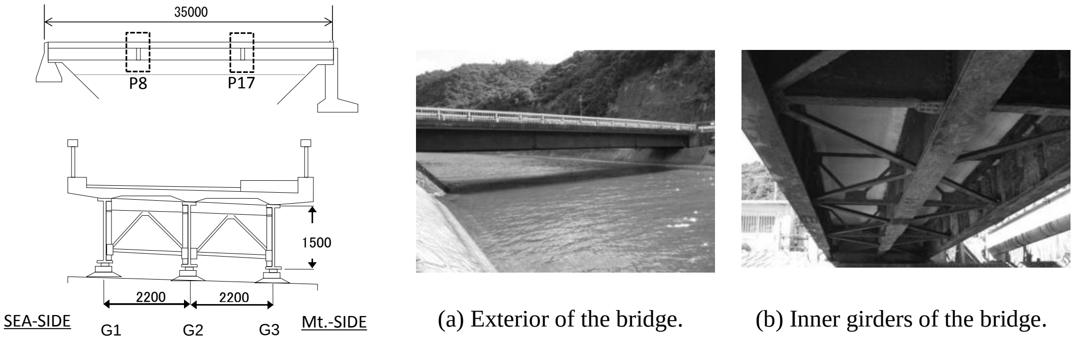
Friction joints with high-strength bolts have been used for the fastener type of steel-girder bridges for the past 60 years in Japan. They actively increase the slip strength by a higher friction coefficient and higher-strength bolts, etc. Consequently, high-strength grip bolted joints have been placed as the main fasteners in the most important structural parts of steel girder bridges. However, high-strength grip bolted joint parts tend to corrode more than the other parts of the bridge. The reason is that the joint parts are difficult to coat sufficiently by painting because of the edges of the nut and the threaded portions. Moreover, aerosol chlorides, which have the most severe corrosive factor, attach to and accumulate on the clearances of the edges of the splicing plates and washers.

Therefore, it is very important to know the relationship between the corrosion behavior of the fastener parts and the slip strength. However, it is extremely difficult to evaluate the data on an actual structure, and there have been few investigations. In this study, corrosion behavior is inspected in detail using corroded specimens cut from the steel girder bridge that collapsed after severe corrosion under corrosive environments for 28 years.

2 THE INSPECTION OF A STEEL GIRDER BRIDGE

2.1 Overview of the Inspection

Fig. 1 shows the steel girder bridge before its collapse. This bridge was fabricated from weathering steel left unpainted, and had three girders with 1500mm girder depth, 2200mm distance between each girder, and 35.0m span. The bridge had been exposed to environmental conditions 50m from the seashore in Okinawa for 28 years, and had been monitored on its corrosive environment and corrosion profiles until its collapse in 2009 due to the severe corrosion of the girder end. It can be seen from the figure that the inner girders in the bridge cross-section are corroded more than the outside girders.



(a) Exterior of the bridge.

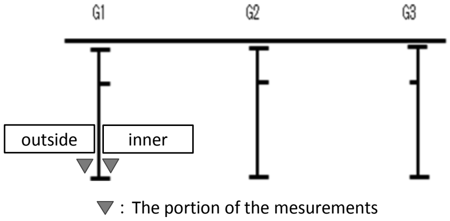
(b) Inner girders of the bridge.

Figure 1. Inspection steel girder bridge.

2.2 The Bridge's Corrosive Environment

The monitoring test was conducted to research the corrosive environment around this bridge. Atmospheric temperature and humidity around the bridge are shown in Fig. 3. The figure also shows the rate of wet periods calculated from measuring temperature and humidity. A wet period is defined as a continuous time in a state of humidity of 80% and higher with a temperature of 0°C and higher (ISO 9223). The average monthly temperature is 26.2°C and the humidity is 78.5%. The rate of the wet periods around the bridge was over 60% between February and June.

To determine the chloride levels around the bridge, the dry gauze method was conducted in accordance with Japan Industrial Standards (JIS Z 2381). Fig. 4 shows the amount of aerosol chlorides measured during every month. The average of aerosol chlorides in every month was 1.9mdd (mg/dm^2/day). It is over the limit value (0.05mdd) to be able to construct a weathering steel girder bridge unpainted, as per Japanese design standards.



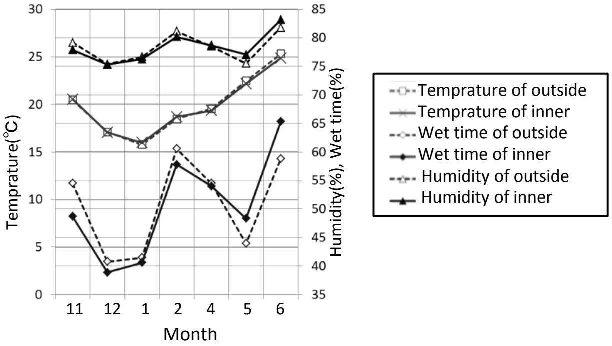


Figure 2. The portion of the measurements. Figure 3. Temperature, wet periods, and humidity.

3 INSPECTION OF THE CORRODED FRICTION JOINT

3.1 Specimens Cut from the Corrosion Bridge

Corroded friction joints connected by high-strength bolts were cut from the web plates of the outer main girders, i.e., G1 and G3, as shown in Fig. 1. Fig. 4 shows the corroded high strength bolts which were removed with the core extraction method from the corroded friction joint. The thickness-reduced quantities of the bolt heads and nuts exposed to corrosive factors (e.g., air, aerosol chlorides, and rain water) were severely intense. The washers were also severely corroded except the surfaces in contact with a bolt head and a nut. On the other hand, the bolt shaft parts sealed by a bolt hole have comparatively maintained their integrity.

Fig. 5 shows the corrosion states of the splice plates. It can be seen that the surfaces of the splice plate are uneven due to the corrosion thinning. However, the progression of the corrosion at the surfaces of the splice plate in contact with washers is inhibited. On the other hand, the corrosion of the surfaces around washers have severely progressed in a doughnut-shape with an approximate 10mm width. Furthermore, the end edges of the fastener plates also have progressed with the corrosion thinning. It can be said from this corrosion profile that the joint parts on the edges of the fastener plates and around washers are more corroded because those parts present a condensed condition with dust and water.

Fig. 6 shows the corrosion aspect of the inner surfaces of the fastener plate. The intense rust can be seen at the edges of inner surfaces of the fastener plate more than the inner surfaces around the bolt holes.

3.2 The Corrosion Thicknesses of Specimens

Corrosion thicknesses were measured at every 10mm on the inner surfaces of the fastener plate with an electromagnetic thickness gage, as shown in Fig. 7. The thickness of corrosion shown is the average value of the triple measurements. The corrosion thicknesses of inner surfaces of the fastener plate are shown in Fig. 8. From this figure, it can be seen that the edges of the inner surfaces are more rusted than the inner surfaces around a bolt hole. These results show that the progression of the corrosion at the inner surfaces around the bolt hole is inhibited by the tensile force given by the high-strength bolts.

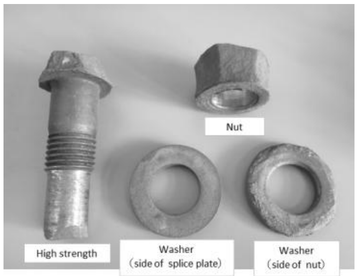


Figure 4. High strength bolts.

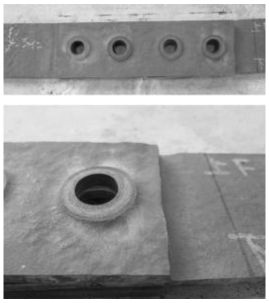


Figure 5. Splice plates.

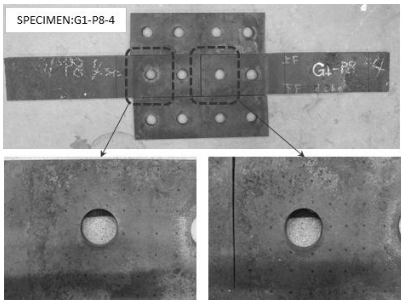


Figure 6. Inner surfaces.

Figure 7. Electromagnetic thickness gage.

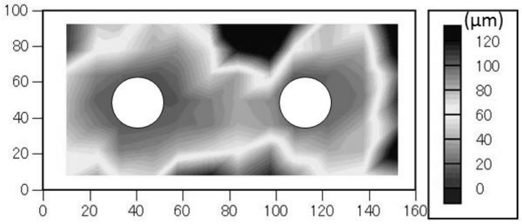


Figure 8. The corrosion thickness.

3.3 The Arithmetic Average Roughness of Specimens

The roughness of the inner surfaces of the fastener plates was measured with a tracer-type surface roughness meter. The arithmetic average roughness (i.e., Ra) that has a relationship with the friction coefficient was applied for this measurement. Fig. 10 shows the contour plots of the arithmetic roughness of the inner surfaces. It can be seen clearly that the edge of the inner surfaces had more roughness than the inner surfaces around the bolt hole, because of the intense rust.

Figure 9. Roughness meter.

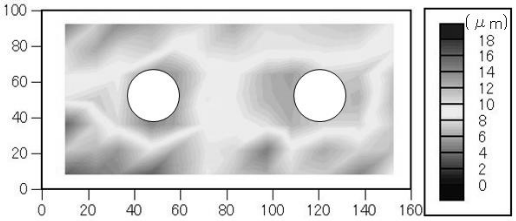


Figure 10. The arithmetic average roughness.

3.4 Calculation of the Friction Coefficient

The friction coefficients of the inner faces of test specimens were evaluated with their arithmetic average roughness measured. The edge of the inner surfaces had intense rust. Therefore, the arithmetic average roughness of the inner surface of specimen at a distance 30mm away from the bolt hole was used for the evaluation. The evaluation was performed using an established transformation method (Minami et al. 2004.). The previous transformation data and equation for the evaluation are shown in Fig. 11.

Table 1 shows the evaluated friction coefficients and the used arithmetic average roughness for the test specimens. These data are also shown in Fig. 11 for comparison purposes. All values of the coefficients show high friction coefficients over 0.6. In terms of arithmetic average roughnesses, there was a dispersion in the measured data. However, it seems that the friction coefficient of the corroded high-strength grip bolted joint parts satisfies the design value, which is 0.4, sufficiently.

Table 1. The friction coefficient.

Specimen	Arithmetic Average Roughness (μm)	Friction Coefficient
G1-P8-3	10.22	0.69
G1-P8-4	9.98	0.68
G1-P8-7	10.08	0.69
G1-P17-5	10.27	0.69

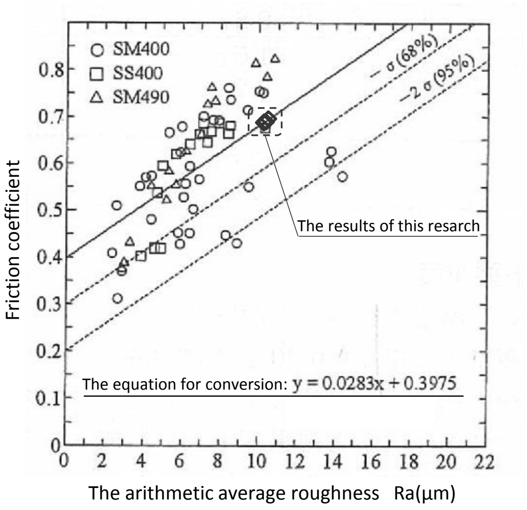


Figure 11. The relationship between Ra and the friction coefficient.

4 CONCLUSIONS

- The corrosion of the edges of the fastener plates progressed positively.
- The progression of the corrosion at inner surfaces around the bolt hole is inhibited by the tensile force given by the high-strength bolts.
- The progression of the corrosion at the surfaces of the splice plate in contact with the washers was also inhibited by the tensile force.
- The friction coefficient evaluated with the arithmetic average roughness measured showed more than 0.40, which is the design value of the friction coefficient.

Reference

Minami, A., Mori, T., and Sugitani, T., The influence of the property of inner surfaces to friction coefficient, *Proc. of the 2004 JSCE Annual Meeting*, November, 2004.