Effect of Weld Penetration on Fatigue Strength of Rib-to-Deck Welded Joints in Orthotropic Steel Bridge Decks

Tokyo Institute of Technology Student Member oCao Vu Dung
Tokyo Institute of Technology Regular Member Kawin Saiprasertkit
Tokyo Institute of Technology Regular Member Eiichi Sasaki

1. INTRODUCTION

Orthotropic steel decks have been widely utilized for long- and medium- bridges including suspension bridges, cable-stay bridges, and urban elevated expressways due to their overall light weight, rapid erection, and structural redundancy. However, fatigue cracking has been frequently observed in rib-to-deck welded joints, resulting from high cyclic stresses in combination with inadequate welding details (Boccieri and Fisher, 1998). One-sided and partial-joint-penetration (PJP) rib-to-deck welds are vulnerable to fatigue cracking due to a localized out-of-plane bending moment, particular in the transverse direction, from the directly applied wheel loads (Miki, 2006).

2. RESEARCH BACKGROUND AND OBJECTIVE

Weld penetration of 75% and 80% of the rib thickness is required in the Japan Road Association (JRA) and the AASHTO LRFD Bridge Design Specifications, respectively. (Ya et al, 2011) suggested that weld melt-through (WMT) and 80% PJP details have comparable strength although WMT seemed to have slightly lower fatigue strengths than the 80% PJP specimens, which is consistent with the findings by Mori (2003), where a deeper weld penetration tends to have a lower fatigue resistance than a shallow one. A shallower weld penetration (for example, an 80% PJP) appeared to have a slightly higher fatigue resistance than a deeper one (for example, a 100% penetration) (Sim & Uang, 2009). Finite-element analyses using effective notch stress method performed by (Sim & Uang, 2012) indicated that a shallower weld penetration at the PJP joint appeared to have a positive effect in enhancing the fatigue resistance. The objective of this research was to evaluate the effect of weld penetration on the fatigue resistance of closed rib-to-deck PJP welds. Fatigue testing was conducted on orthotropic deck specimens with two degrees of penetration, namely 75% and 100%, without WMT, fabricated with WMT controlling techniques.

3. TEST SETUP AND LOADING SCHEME

Four full-scale specimens were manufactured by Mitsubishi Heavy Industries Bridge & Steel Structures Engineering Company Ltd. SM400A steel was used for the specimens. Fig. 1 shows the plan, elevation, and cross-sectional views of the test specimens. Each specimen consisted of a 12-mm-thick deck plate and a 6-mm-thick rib. The specimen was supported by two supporting diaphragms as a simple beam. Specimens 1 (S1) and 2 (S2) were fabricated with 100% penetration (i.e., full penetration) while specimens 3 (S3) and 4 (S4) with 75% penetration (PJP) (fig. 2). Fig. 3 shows the test setup with an actuator centered on top of the deck plate of the specimen. The applied load from the actuator simulated a single truck wheel load of 50 kN, half of the design axle load of 100 kN required by JRA. The size of the loading pad was 20 cm x 20 cm.

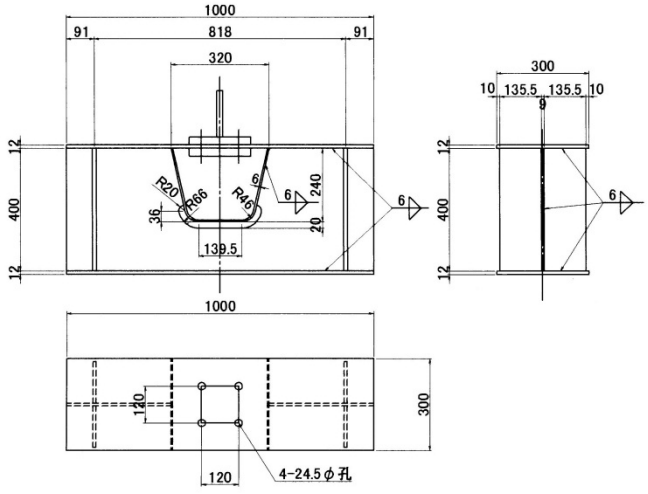


Figure 1 – Specimen configuration

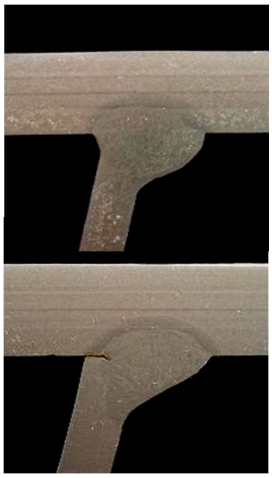


Figure 2 – Full penetration (above) and PJP

Figure 3 – Test setup

Keywords: Fatigue, weld penetration, orthotropic, bridge, steel decks, rib-to-deck, welded joints
Contact address: Tokyo Ins. of Technology, 2-12-1 Ookayama, Meguro-ku, Tokyo, 152-8552, Japan, Tel: +81-3-5734-3099

The initial target loading ranged from -5 kN to -55 kN, which was shifted to +5 kN to -45 kN after 50% strain drop had been observed at all strain gauges. Nine strain gauges were located along the weld line, at 5 mm away from the weld toe (in case of full penetration) or the rib edge (in case of PJP), under the deck plate, and inside the rib. Strain measurement was conducted at both sides of the loading pad, i.e. both weld lines at west side (W) and east side (E).

4. EXPERIMENTAL RESULTS

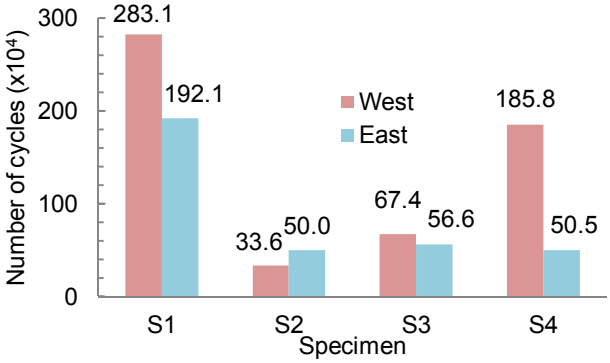


Figure 4 - Number of cycles at first 50% strain drop

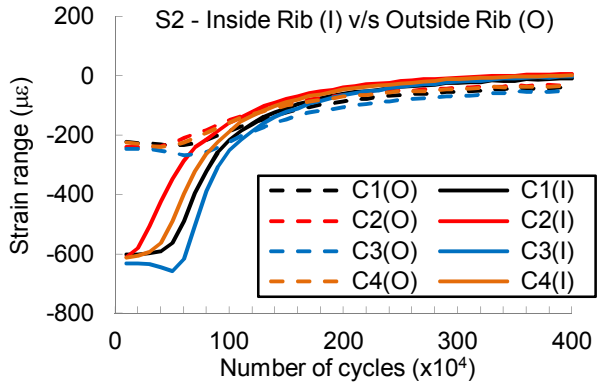
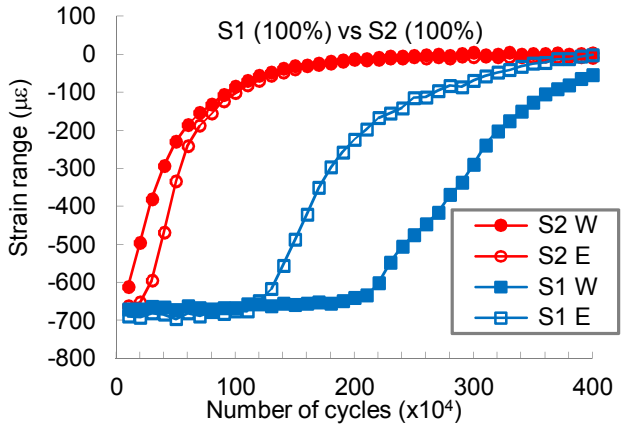
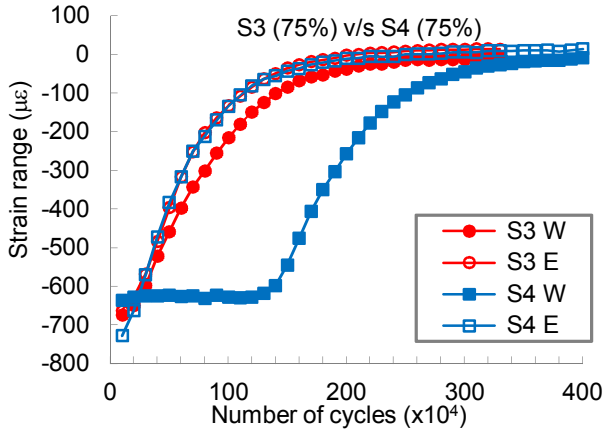


Figure 5 – Strain range recorded at four corners (C1-C4) of S2



(a)



(b)

Figure 6 – Strain range variation (at crack initiation point) comparison between S1 and S2 (a), S3 and S4 (b)

The S1 appeared to experience the first 50% strain drop at both sides later than the remaining specimens (fig. 4), which may indicate the highest fatigue strength. However, there was a large difference between the rate of strain drop measured at S1 and S2 (fig. 6, left). The difference suggests that S2 have significantly lower fatigue strength than S1. Meanwhile, S3 and S4 seemed to have comparable fatigue strength (fig. 6b). The strain ranges inside the rib appeared to be about three times higher at the beginning and experience a larger variation than those outside the rib (fig. 5).

5. CONCLUSIONS

The effect of weld penetration on the fatigue resistance of rib-to-deck welded joints was evaluated by strain measurement on specimens fabricated with 75% and full penetration. Under the described loading condition, cracks were not likely to initiate from the weld toe outside the rib. Full penetration seems not to have higher fatigue resistance than the PJP. Further investigation is required to determine the cause of the large variation in the fatigue strength of the full penetration specimens.

6. REFERENCES

Bocchieri, W.J., and Fisher, J.W.: Williamsburg Bridge replacement orthotropic deck as-built fatigue test. ATLLSS Rep. No. 98-04, 1998, Lehigh University, Bethlehem, Pa.

Miki, C.: Fatigue damage in orthotropic steel bridge decks and retrofit works. In. J. Steel Struct., 6,(4), 255-267, 2006.

Ya, S., Yamada, K., and Ishikawa, T.: Fatigue evaluation of rib-to-deck welded joints of orthotropic steel bridge deck. J. of Bridge Eng., ASCE, 16(4), 492-499, 2011.

Sim, H.B., Uang, C.M., and Sikorsky, C.: Effect of fabrication procedures on fatigue resistance of welded joints in steel orthotropic decks. J. Bridge. Eng., 14(5), 366-373, 2009.

Sim, H.B., and Uang, C.M.: Stress analyses and parametric study on full-scale fatigue tests of rib-to-deck welded joints in steel orthotropic decks. J. Bridge. Eng., 17(5), 765-733, 2012.