Effect of weld-melt through on fatigue strength of trough-to-deck welded joint

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1.Objective

Fatigue cracks, as shown in Fig.1, especially root-deck crack, initiating from weld root and propagating into deck plate of trough-to-deck welded joint of orthotropic steel deck has increasingly received much attention. One of the main factors which affects fatigue crack is weld penetration. The weld penetration is at least 75% of rib thickness in Japan[1)] and 80% in USA[2)]. Because weld root is inside the trough and then difficult to control in fabrication. In some case, the weld metal may be melted through the web of trough rib, which is called herein as weld melt-through (WMT)[3)]. In this study, the effect of WMT on fatigue strength of the joint is studied by plate bending fatigue tests which were carried out in Nagoya University using small-scale specimens made by cutting out full-scale test specimens[3)].

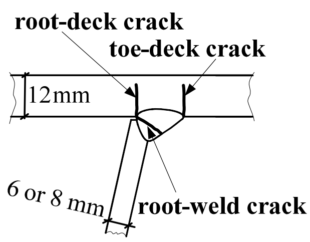


Fig.1 Fatigue cracks

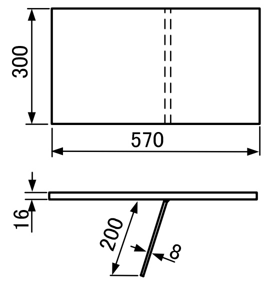
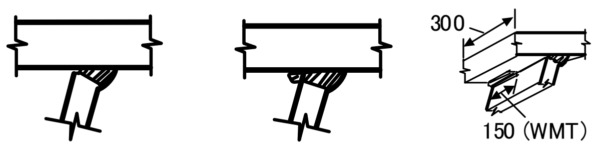


Fig.2 Test specimen



(a) 80%PJP **(b)** WMT **(c)** 80%PJP&WMT

Fig.3 Weld conditions of trough-to-deck joints

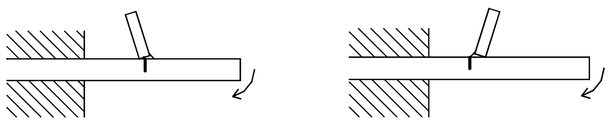
2. Plate bending fatigue test

Test specimens

Twenty small-scale test specimens of 300 mm wide, as shown in Fig.2, were used for the plate bending fatigue tests. They were cut out from some selected welded joints of longitudinal trough-to-deck welded joints of full-scale specimens which had been fatigue-tested in the University of California, San Diego[3)]. The thickness of deck plate and rib was 16 and 8 mm, respectively. The joints were made with submerged arc welding (SAW) process. After being cut out, the small-scale specimens were arranged into three groups based on which the joints they were cut from full-scale specimens of different weld conditions: (a)80%PJP, (b)WMT and (c)80%PJP&WMT, as shown in Fig.3. Observing on test specimens shows that some of (a)group also contained some spots of WMT and WMT joint did not run continuously over the weld line. It seems that control of weld penetration is difficult.

Fatigue test set-up

The fatigue tests were carried out using vibration-based fatigue testing machine[4)]. The fatigue test setups are schematically shown in Fig.4, which fatigue cracks from weld root and from toe were intentionally simulated for comparison. In each series of test setup, three abovementioned weld conditions were tested. The stress ratios were 0.2. Copper wires were glued to the surface of deck plate to detect fatigue cracks. The test was terminated when the copper wires were cut by fatigue crack and the number of cycles at this stage is defined as fatigue life of the joint in this study.



(a) for root-deck crack **(b)** for toe-deck crack

Fig.4 Test set-up intended for cracks from root or toe

Keywords: fatigue test, fatigue crack, fatigue strength, weld penetration, orthotropic steel deck
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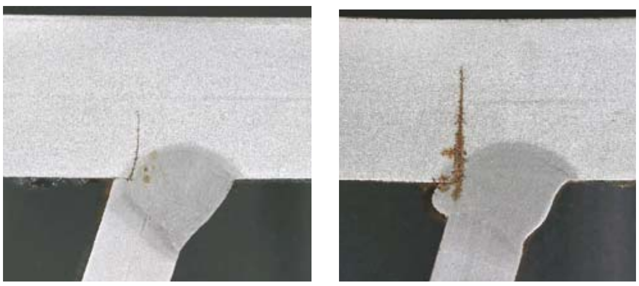
3. Fatigue test results

Fatigue crack behaviors

For the test set-up intended for root-deck crack, fatigue cracks occurred from weld root and propagated into deck plate as planned. For the test set-up intended for cracking from weld toe, fatigue cracks occurred from weld root. Only one specimen in each series had toe cracking which was secondary to root-cracking. Therefore, it is suggested that failure from weld root is more likely than from weld toe for the rib-to-deck joint under study. The reason might be the weld profile at root is poorer than at weld toe due to difficulty in control of weld root condition.

The typical macro-sections of the trough-to-deck welded joints are shown in **Fig.5**. The fatigue crack paths are nearly perpendicular to deck plate. The welded metal in weld root overlapped the deck plate for WMT detail.

Observation on fracture surfaces showed that fatigue cracks seem to have initiated from the locations with the spots of WMT or in the WMT side of (c)80%PJP&WMT group. It is likely that presence of weld melt-through reduces fatigue strength of the welded joint. If the specimens with presence of WMT are grouped into one group called as *(II)WMT*, and the rest as *(I)80%PJP* (without any WMT), then we may say *(II)WMT* is poorer than *(I)80%PJP*.



(a) 80%PJP **(b)** WMT

Fig.5 Macro-sections

Comparison between *(I)80%PJP* and *(II)WMT* in S-N diagram

The fatigue test results of *(I)80%PJP* and *(II)WMT* groups are plotted in **Fig.6**. The stress range is computed at weld root by interpolation of measured stress ranges in weld root/toe sides. As mentioned earlier, fatigue life is taken at the termination of fatigue test.

Regression analysis is carried out on each group of test results. The mean regression S-N line of each group, its equation and its standard deviation s are also shown in **Fig.6**. The regressed S-N line of the WMT is slightly lower than that of the 80%PJP. The fatigue strengths of the details at 2×10^6 cycles are as follows: *(I)80%PJP*—103, 110 and 119 MPa, and *(II)WMT*—90, 102, 116 MPa, respectively at mean-2s, mean and mean+2s. Thus, the WMT is slightly poorer than the 80%PJP; the difference is around 8% at mean value. Thus, it should be careful with presence of WMT in the joint. Previous study[3] also found, by using full-scale specimens, that the WMT seems poorer than the 80%PJP.

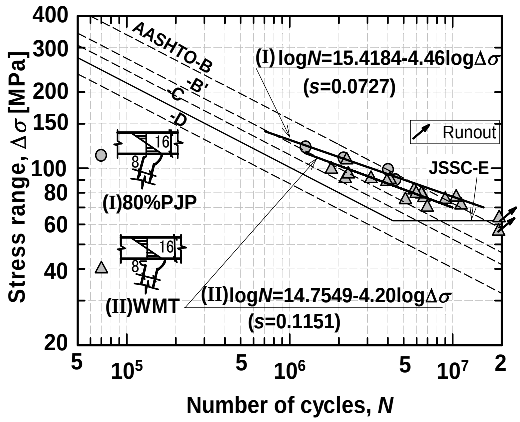


Fig.6 Comparison between 80%PJP and WMT

4. Conclusion

The main points of this study are as follows:

- Weld root seems to be poorer than weld toe,
- Presence of weld melt-through may reduce fatigue strength of the welded joint. That is, WMT is poorer than 80%PJP. Thus, it should be careful with presence of WMT in the welded joint.

References

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2) American Association of State Highway and Transportation official, LRFD Bridge design specifications, 2004.

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4) Plate bending fatigue tests for root crack of trough rib of orthotropic steel deck, *J. Struct*, JSCE, Vol.54A,pp.675-684, 2008. (in Japanese)