Analytical investigation for Fatigue Cracking from Weld Roots between Deck Plate and U-rib in Orthotropic Steel Decks

Kyushu University Student member ○M.Yang Fellow member S.Kainuma Regular member Y.S.Joeng
Yokogawa Bridge Corporation Regular member S.Inokuchi
JFE Engineering Corporation Regular member A.Kawabata
Mitsui Engineering & Shipbuilding Co., Ltd. Regular member D.Uchida

1. Introduction An orthotropic steel deck directly resists vehicle loads and transmits vehicle loads to the main bridge girders, and its structural behaviors and responses are characterized by the structural interaction and loading conditions. However, diverse fatigue cracks have also been reported on the deck plate-rib and rib-floor beam welds as a result of their relatively slender geometries[1] and the tensile residual stress could existed at the partial joint penetration (PJP)[2]. The root cracks initiate from the weld roots and then propagate through thickness of deck plate, it cannot be observed by visual inspection. In this study, the structural responses of an orthotropic steel bridge deck with the partial joint penetration welds between deck plate and U-rib was analytically evaluated. Three-dimensional FE models were constructed using one elasticity model for analysis. In addition, the results of the finite element calculations were compared with fatigue test results which were carried out on full-scale specimens.

2. Fatigue test and results This experimental system focused on root cracks located in the field between crossbeams. It consists of two hydraulic jacks; one of them is the static jack and another is the dynamic servo jack, loading positions as shown in Fig.1. [3]

The fatigue tests system were carried out with full-scale specimens named D12U8SP50, which dimensions as shown in Fig.2. Test results as shown in table 1. D12U8SP50-2 specimen was only be loaded as compressive cyclic stress, and the root crack not occurred in this case. The larger part of stress range exists in the tension zone, the longer length

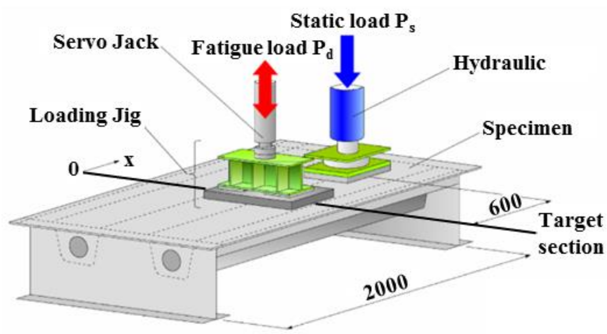

Fig.1 Fatigue experimental system(mm)

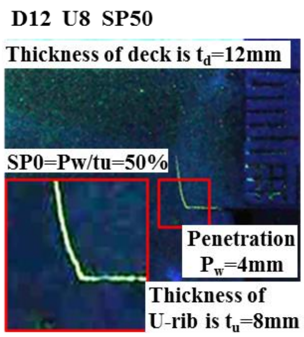

Fig.2 Parameters of test specimens

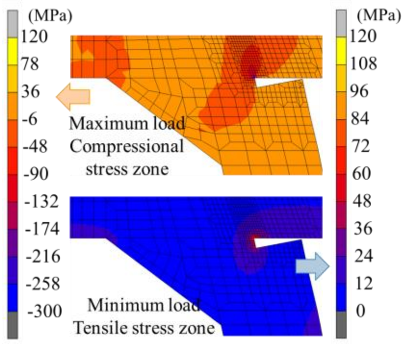

Fig.3 Maximum principal stress contour

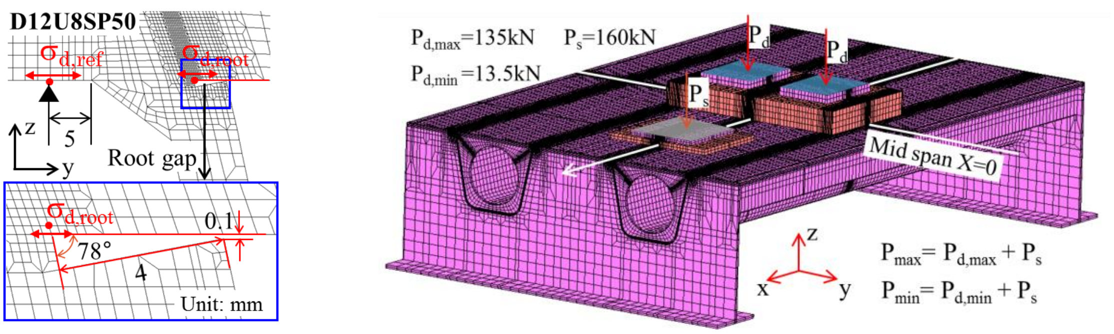

Fig.4 FEM model and load conditions

Table 1 Test results

Specimens	Position X(mm)	Stress(MPa) σ_{max}	Stress(MPa) σ_{min}	Stress ratio R	Loading cycles N(10^4)	Crack length(mm) Root	Crack length(mm) Toe
D12U8SP50-1	150	-160	20	-0.13	1,000	3.8	0.0
	-50					0.8	2.5
D12U8SP50-2	0	-180	0	0	300	0.0	0.0

Keywords: Orthotropic Steel Decks; Fatigue Test; Root Crack; FE analysis
744, Motooka, Nishi-ku, Fukuoka 819-0395 Kyushu University

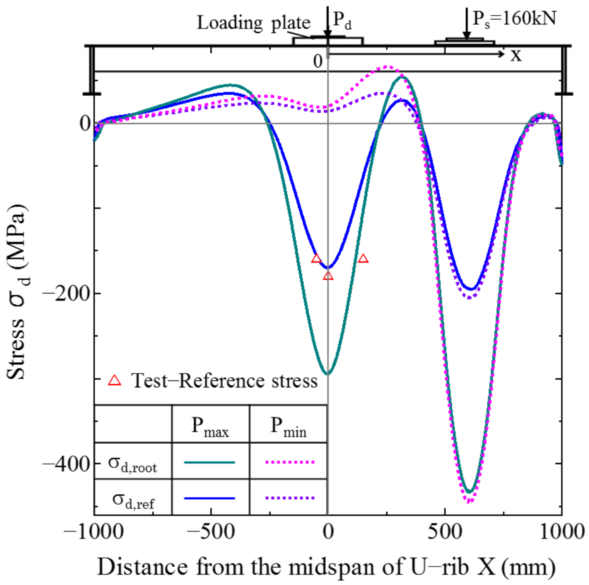

Fig.5 Reference stress waves of model

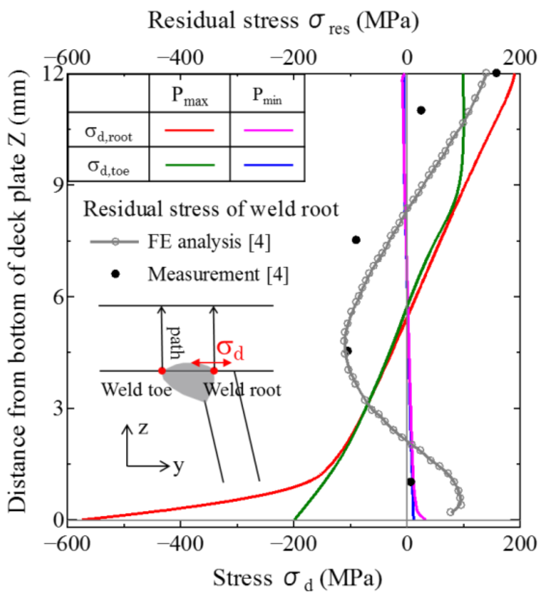

Fig.6 Stress distribution of deck plate in mid-span

cracking. It was suggested that the tensile stress is closely related to initiation and propagation of the root crack. Consequently, crack propagation tend to be easier to happen with the decrease of stress ratio under same stress range.

3. FE analysis In order to investigate the structural responses of an orthotropic steel bridge deck with the partial joint penetration welds between deck plate and U-rib, an elasticity model with root gap was built. A three-dimensional FE analysis model was created using the Marc 2012. An elastic modulus of 206,000MPa and Poisson's ratio of 0.3 were applied as the steel material properties. The dimension of FE model and reference stress points are shown in Fig.4. The mesh size of stress concentration zone is 0.2×0.2mm.

Maximum principal stress contour of FE model as shown in Fig.3. It also showed that local stress concentration near root gap is more obviously than that in weld toe, which consistent with the test results. Root gap location would being tensile stress zone under minimum load case and being compressive stress zone under maximum load case.

The transverse stress of FE analysis results were compared with those of test results in Fig.5. FE analysis and test results were to be similar behavior. Besides, the peak stress value of weld root in mid-span is much higher than reference stress of weld toe. It may attributable to stress concentration near root gap for its sharp geometries. So stress distribution in Z direction of deck was calculated as shown in Fig.6. The tensile stress of weld root and toe reached the maximum difference is about 215% while the stress range reached around 236% under minimum load case at the bottom of the deck. The maximum stress of weld root is much higher than that in weld toe when the distance is less than 2mm away from the bottom of the deck plate. In addition, it was compared with the FE and measured initial residual stress of this structural detail in deck thickness direction, the residual stress occurs could lead to increase the maximum tensile stress value of effective stress[4]. It was considered that the tensile residual stress decreases the stress ratio at the PJP. Compressive stress areas of initial residual stress near the neutral axis (z=6mm) also proved the tensile stress in crack top may be offset and lead to crack propagation stop.

4. Summary

1) Stress response of FE analysis were shown in to be similar distribution with test results.
2) Weld root is easier to cracking than weld toe under the load case for this structural detail.
3) The crack initiation at root tip tend to be effected by its tensile residual stress, while residual stress closely related to propagation of the root crack.

Reference

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