Fatigue Life evaluation of Orthotropic Steel Deck Detail.

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1. Introduction

Orthotropic steel decks are lighter than concrete decks and are extensively used for long span bridges and elevated urban highway bridges. They are subject to wheel loads and their fatigue assessments are required when a large number of heavy wheel load are anticipated. Photo 1 illustrates a case where a crack occurred at the welded joint between the deck plate and the trough rib. Fig.1 (a) and (b) schematically show a typical cross section of orthotropic steel deck subject to wheel load, and an example of detail of trough rib welded to deck plate, espectively. Among various welded details, the authors intend to carry out a fatigue evaluation of a welded detail between the deck plate and the trough rib as shown in Fig.1-(c). This detail will named the object detail.

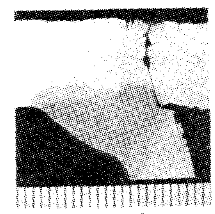
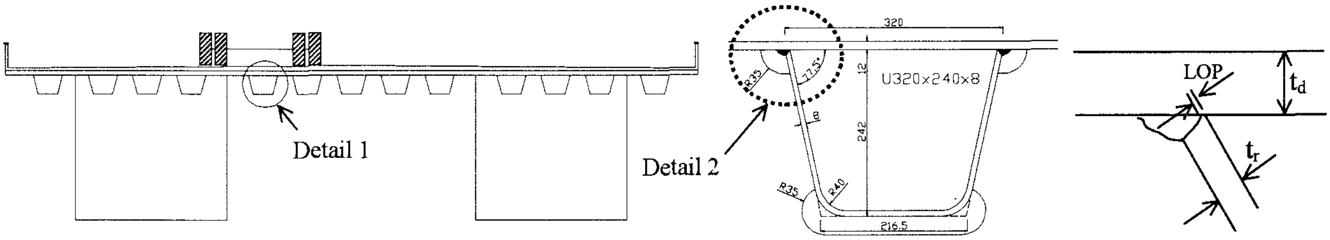


Photo 1



(a) Typical transverse section of orthotropic Steel Deck (b) Detail 1 (c)Detail 2: Trough-to-deck Joint

Fig. 1: Orthotropic Steel Deck and the joint to be considered

2. One-mm stress method and its correlation with detail under consideration

One-millimeter stress method is a method for determining a geometric stress for fatigue strength evaluation of welded joints, and is based on the computed stress value at 1mm below the weld toe in the direction along which the crack is expected to propagate. A significant advantage of this method is that it can establish the correlation between the fatigue strength of a reference detail and that of an object detail whenever the former and the latter have similar characteristic regarding the way of propagation of crack.

The correlation can be made by a quantity called *global* stress concentration factor (SCF) due to structural geometry change, designated as $K_{t,global}$ and expressed by the following expression:

$$K_t = K_{t,local} \times K_{t,global},$$

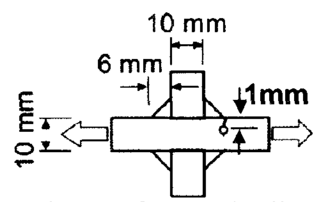


Fig.2: Reference detail

in which K_t, $K_{t,local}$ are the *whole* SCF and SCF due to weld profile, respectively. The former is obtained from Finite Element Analysis (FEA) on specimen under consideration. However, the latter is thought to approximate the SCF from FEA on the reference detail. Both parameters are taken at 1mm away from the weld toe along the anticipated crack path assuming no crack existence. The reference detail is assumed to be a cruciform joint as shown in Fig.2. Performing FEA on this cruciform joint indicates that the 1mm-location SCF of this detail is closed to unity. Therefore, the value of global SCF, $K_{t,global}$, can be taken directly as that of SCF of the object detail.

According to inspections along with destructive tests made recently on an orthotropic steel deck bridge, the cracks were found to initiate from the weld root and propagate through the deck plate thickness as depicted by photo 1. Furthermore, various experiments conducted on the reference details, which were the cruciform joints, have proven that the cracks initiated from the weld toe and propagate into the thickness of the parent plate. Consequently, the similarity between object detail and the reference detail regarding the way that crack propagates is proven. The one-millimeter stress method is applicable in this case.

3. Approach Concept and FEA modeling

Let us designate t_d, t_r and LOP as a deck plate thickness, trough rib thickness and lack of penetration, respectively (Fig. 1-(c)). Table.1 below shows the parameters used in modeling the object details for the analyses. Each analysis was performed so as to evaluate the SCF of an object detail (i.e. K_t) under two separate loadings: a tensile load and a bending moment, as depicted by Fig.3. The SCF is defined as the ratio of the 1mm-location normal stress on the section along which the crack is anticipated to the nominal stress taken at the uttermost fiber.

Table.1

t_d(mm)	12		18	
t_r (mm)	6	8	8	9
LOP (%)	0	20		40

Up-to-here analysis is termed *local* analysis. This local analysis is expected to correlate with other analysis, termed *global* analysis. This correlation leads to an evaluation of the fatigue life of orthotropic steel deck bridge. The global analysis deals with analysis of the whole panel of orthotropic steel deck, and evaluates the stress range occurred at the joint whose fatigue strength derived from local analysis. This work is required further research.

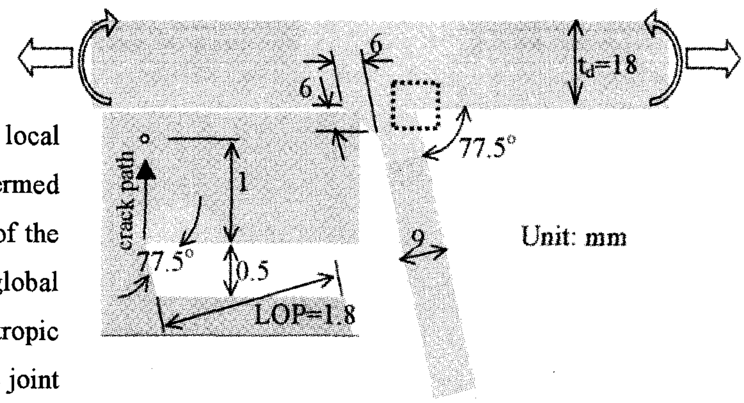


Fig.3: A FM model with 20% of LOP

4. Fatigue strength evaluation of trough to deck joint, LOP effect, thickness effect

As the bending stress is usually dominant in the deck plate, we mainly focused on the specimens subject to bending moment. Fig.4 is an example of expected S-N curves of a detail (t_d=18 mm, t_r=9 mm and without LOP) under bending moment loading. The dash lines represent the data range of the reference detail, which comes from the fatigue test. However, the bolt lines represent the data range of the plotted object detail resulted from division of that of the reference detail by a factor $K_{t,global}$ of this object detail. Table.2 shows the expected fatigue strength (lower bound) at 2x10^6 cycles of studied trough-deck joints.

Table.2

	Bending Load			Tensile load		
LOP (%)	0	20	40	0	20	40
D12R6	104.8	105.3	105.8	85.7	86	86.4
D12R8	104.3	104.8	105.3	85.4	85.7	86.1
D18R8	91.9	93	94.2	81.9	82.6	83.5
D18R9	91.3	92.4	93.7	81.5	82.3	83.1

(Note: Numbers preceded by D and R are deck plate thickness and rib wall in mm, respectively.)

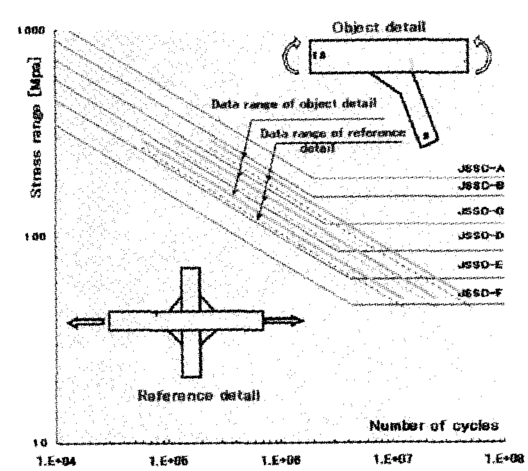


Fig.4: S-N curve of D18R9 model without LOP

It can be seen that the fatigue strengths of the specimens under tensile loading and bending moment are above the class E of JSCE. From this table, it seems that fatigue strength decreases as deck plate and trough rib become thicker, and slightly increases as LOP increases.

5. Reference

Xioa ZG, K. Yamada. A method of determining geometric stress for fatigue strength evaluation of welded joints. International Journal of Fatigue, 2004.