Fatigue Evaluation of Steel Post Structures Based on One Millimeter Stress

Zhi-Gang XIAO, Department of Civil Engineering, Nagoya University, Student Member of JSCE
Kentaro YAMADA, and Tatsuya OJIO, Graduate School of Environmental Studies, Division of Environmental Engineering and architecture, Nagoya University, Members of JSCE

1. Background of Research

Steel posts are usually used to support lightings and traffic signs on highway bridges, Fig.1. The bottom end of post is usually welded to a baseplate, which in turn is attached to the bridge structure through high-strength anchor bolts. To strengthen the connection between the post and baseplate, four or eight triangular gussets are usually welded to both the post and the baseplate. The gussets can increase section modulus of the post, but will introduce stress concentration at gusset tip. Vibration of the post caused by traffics and/or wind loading may generate essential cyclic stresses at gusset tips and initiate fatigue cracks. New types of post-baseplate connection have been proposed by some researchers, and fatigue experiments carried out on some of them.

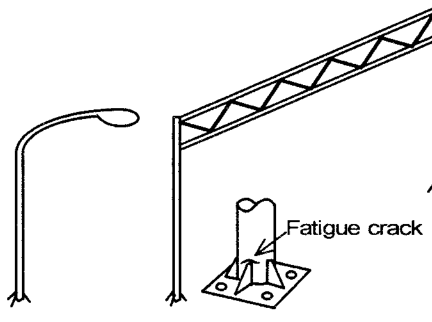


Fig.1 Fatigue crack of post structures

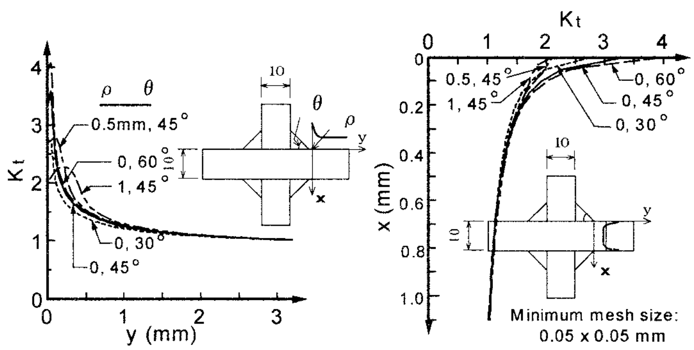


Fig.2 Stress distribution of reference detail

Since fatigue experiments are both time- and money-consuming, structural analysis based fatigue evaluation is highly necessary. The writers have proposed an approach to evaluating fatigue strength of fillet welded structures based on a characteristic stress value along expected crack path and demonstrated its feasibility with fatigue test results of some typical details[1]. In this study, this approach was applied to evaluate fatigue strength of typical and two improved types of post structures. Evaluations were also compared with available fatigue test results.

2. Fatigue Evaluation Based on One Millimeter Stress

Fatigue crack in fillet welded joints usually forms at weld toe where exists high stress concentration, and the extent of stress concentration determines the magnitude of fatigue life to a large extent. Both the local shape of weld toe and the global geometry of welded joints contribute to the stress concentration at weld toe, as shown in Eq. (1).

$$K_t = K_{t,local} \times K_{t,global} \qquad (1)$$

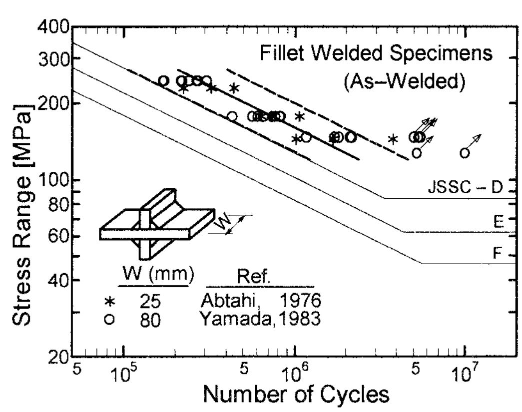
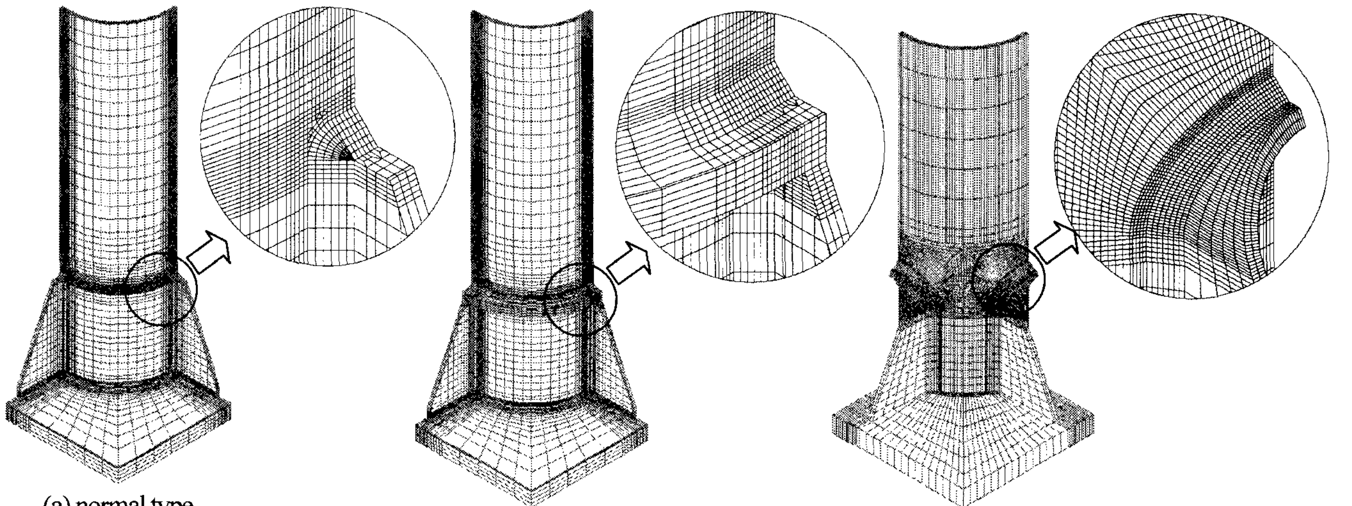


Fig.3 Fatigue test data of reference detail

where, $K_{t,local}$ and $K_{t,global}$ indicate stress concentration due to weld toe geometry and other geometries in the welded joint, respectively. Weld profile, especially weld toe shape, is hard to control, and $K_{t,local}$ is random and largely scattered, while $K_{t,global}$ is determinate and joint-specific. FEA shows that, in a non-load-carrying cruciform joint with the dimension of 10mm in thickness of attachment and main plate and 6mm in fillet weld leg, hereinafter referred to as reference detail, the stress concentration factor at 1mm in depth at weld toe section is close to one, Fig.2. Besides, the stress at that point does not change with local parameters of weld toe, which implies that the affecting region of weld toe geometry is limited within 1mm in depth. Stress concentration at that location is chosen to represent $K_{t,global}$. Fatigue test results of non-load-carrying cruciform joints with comparable sizes as the reference detail are compiled (Fig.3) and employed for fatigue evaluation of fillet welded details.



(a) normal type

(b) ring-strengthened

(c) U-stiffener type

Fig.4 Quarter models of post structures

3. Fatigue Evaluation of Post Structures

The normal type and two improved types of post-baseplate connections are studied. Fig.4 shows examples of FEM model. By taking advantage of symmetry, a quarter of the structure is analyzed for all cases. Fig.5 shows the stress distribution through wall thickness at critical point location under tensile loading, with the origin of x-axis at outer surface of post wall. The phenomenon that the inner post surface of normal type is in compression shows that substantial local bending was induced at gusset tip. The main reason for this is the gusset's being out of alignment with anchor bolts, which causes gusset tip to deform outward under tensile loadings. In the two improved forms, the inner surface is in tension, and the stress concentration at outer surface is significantly decreased.

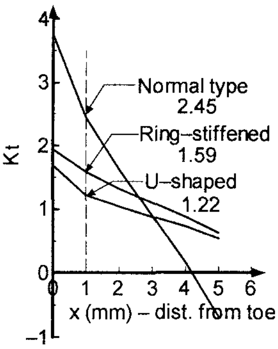


Fig.5 Kt through post wall

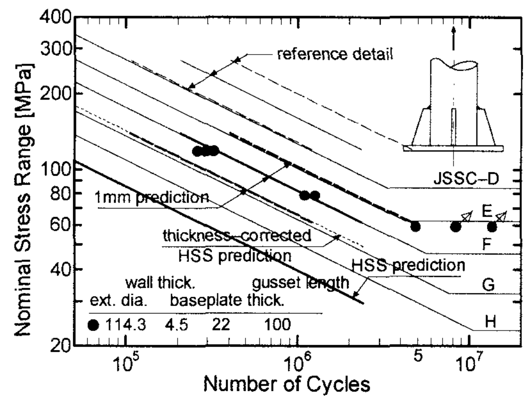


Fig.6 Fatigue evaluation and test data

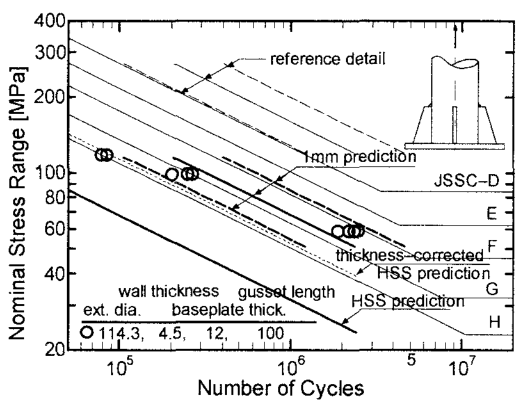


Fig.7 Fatigue evaluation and test data

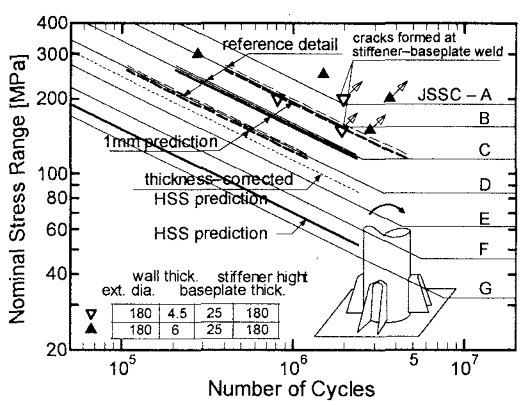


Fig.8 Fatigue evaluation and test data

To validate the feasibility of one millimeter stress approach, fatigue test results of post structures are collected and compared with evaluation. Figs. 6 and 7 show test results on small size normal type specimens of Yamada[2]. Well agreement between evaluation and test results is shown. Fig. 8 shows test results and evaluation of U-stiffener specimens experimented by Nippon Steel Corporation[3], where test results are much higher than evaluation. Evaluations by hot spot stress method (HSS) are also plotted in these figures. Thickness corrected HSS evaluations are in good agreement with those of one millimeter stress approach.

Reference 1. Yamada K, Xiao Z G, Kim I T, Tateishi K, Re-analysis of fatigue test data of attachments based on stress at fillet weld toe, *J. Struct. Engrg., JSCE,* Vol.48A, pp.1047-54, 2002. 2. Yamada K, Kondo A, Kobayashi K, Miyamoto S, and Araki J, Fatigue strength of steel lighting pole's tubular flange joints, *J. Struct. Engrg.*, JSCE, Vol.38A, pp.1045-1054, 1992. 3. Nippon Steel Corporation, *Technical material of Nippon Steel Corporation*, 2000.