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INFLUENCE OF FILLET RADIUS ON THE FATIGUE STRENGTH OF FLANGE-GUSSET JOINTS

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The influences of the transition radius of fillet, and the width of flange on the fatigue strength of flange gusset joints are examined by using the fracture mechanics concept. The results of this study have been used as basis for revision of fatigue design code for the Honshu-Shikoku Bridges.

Keywords : fatigue, gusset, high strength steel

1. INTRODUCTION

In the stiffened truss of suspension bridges, there are many gusset joints with various structural details. Among these, a groove-welded flange-gusset joint and a joint which is cut off from base material are important ones in the fatigue design of stiffened truss. The former is used for attachment of floor truss to the main truss chord, and the latter is used for a main truss pannel point where the web is incorporated into the gusset. At the end of these gusset plates, stress concentration due to sudden changes of configuration causes a decrease in fatigue strength. This stress concentration is dominantly influenced by the transition radius of fillets. However, in the 1977 design code for the Honshu-Shikoku Bridges[1] and in the 1974 design code for the Japanese National Railways[2], these joints were classified each as the same category in spite of transition details. That is, the former was classified as category B on the condition that the fillet radius was larger than 20 mm, and the latter was classified as category B in design code for the Honshu-Shikoku Bridges and as category A in the design code for the Japanese National Railways on the condition that the end of fillet was smoothly finished by grinding.

As the supplement of previous paper[3], the influence of transition radius of fillet on the fatigue strengths of gusset joints are examined by using the fracture mechanics method in this paper. The results of this study have been used as the basis for the revision of fatigue design code for the Honshu-Shikoku Bridges in 1982[4].

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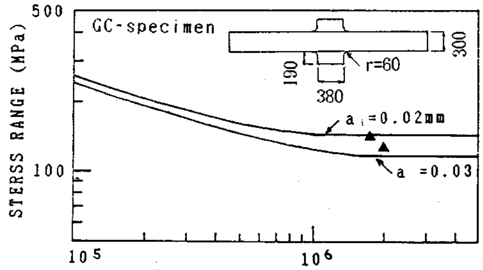

Fig. 1 Predicted Sr-Np relations and test results (GC-specimens).

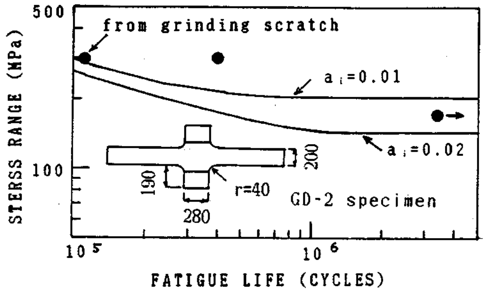

Fig. 3 Predicted S_r-N_p relations and test results (GD-specimens).

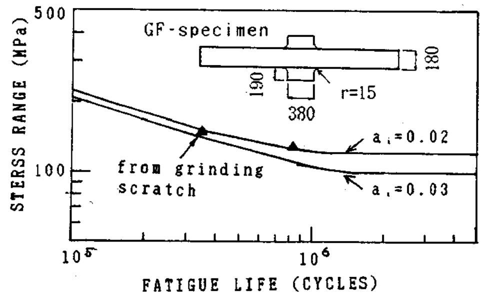

Fig. 2 Predicted S_r-N_p relations and test results (GF-specimens).

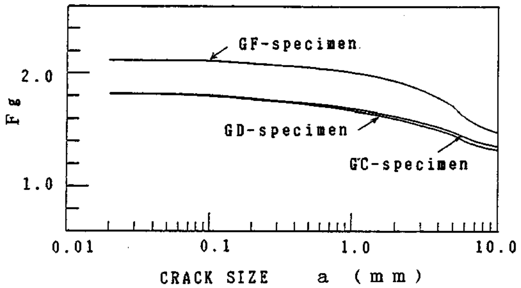

Fig. 4 F_g decay curves.

2. ANALYTICAL METHOD

Joints as the object of this analysis are a groove-welded flange-gusset joint and a joint cut off from the base material. Among the specimens which were reported in the previous paper[3], the ones as the object are GC and GF specimens which simulate the former joint, and GD specimens which simulate the latter joint. The latter joint is classified into non-welded joints in the design code for the Honshu-Shikoku Bridges, but a corner weld exists near this joint in actual truss chord and the corner weld induces high-tensile residual stress in the vicinity of the end of gusset joint. Therefore, the following relationship between fatigue crack growth rate (da/dN) and stress intensity factor range (Δk)[5] which authors obtained experimentally about welded joints was employed for the prediction of the fatigue life.

$$dA/dN = 5.47\times10^{9}(\Delta K^{3}-2.5^{3}) \quad da/N\ (\mathrm{mm/cycle}),\ \Delta K\ (\mathrm{MPa}\sqrt{\mathrm{m}}) \cdots\cdots (1)$$

Assuming that the crack was through edge type crack, the stress intensity factor range was calculated by the equation below[7].

$$\Delta K = F_s\cdot F_g\cdot F_t\cdot S_r\sqrt{\pi a} \cdots\cdots (2)$$

where, S_r is stress range, F_s is a correction factor for the surface crack, F_g is a correction factor for the stress gradient, and F_t is a correction factor for the width of plate. These factors used here are expressed as follows :

$$F_s=1.12,\quad F_t=\sqrt{sec\,(\pi a/2\,W)}$$

where, W is the width of plate, and a is crack size. F_g was computed from the stress distributions which were obtained by using the finite element analysis. Here, the plane stress element was used. The size of elements in the vicinity of the end of fillet was 0.02 mm×0.02 mm. The stress concentration factors of GC, and GD specimens are 1.8, 2.2 and 1.8, respectively. Fig. 4 shows F_g decay curves in the direction of the width of the plate at the end of fillet.

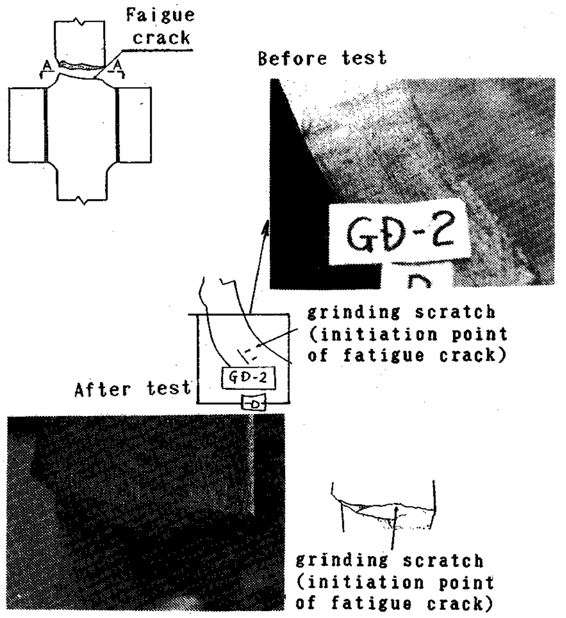

Fig. 5 Failure surface of GD-2 specimen.

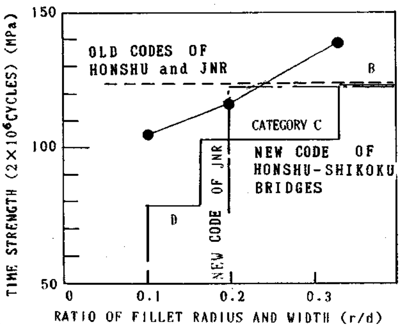

Fig. 6 Analytical results and design category (welded flange-gusset joint).

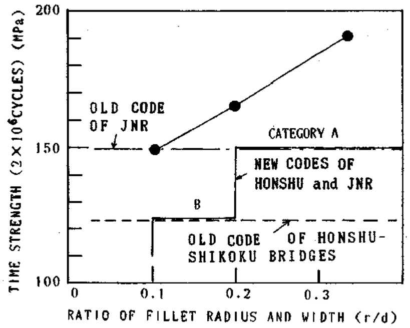

Fig. 7 Analytical Results and design category (joint cut off from base material).

3. INITIAL CRACK SIZE

When fatigue life is to be predicted, the initial crack size have great influence on the results. The final crack size is not a sensitive factor as the crack growth rate rises acceleratedly according as the crack size becomes larger. Fig. 1, Fig. 2 and Fig. 3 show the experimental results and the fatigue crack propagation lives which were calculated changing the initial crack size (a_i). Fig. 5 shows the fatigue failure surface of GD-2 specimen. In this specimen and GF-1 specimen, fatigue cracks initiated from grinding scratch. Specimens which are specially fabricated for laboratory fatigue test are apt to be fabricated more elaborately than the actual structure. It is thought that this kind of grinding scratch cannot be avoided in the actual structure. The initial size of crack which was assumed to be through crack was set at 0.03 mm for the welded flange gusset and at 0.015 mm for the joint cut off from the base material. These sizes are nearly lower bounds of the test results shown in Fig. 1 and Fig. 2, and Fig. 3. As shown in Fig. 8 and Fig. 9 in the previous paper[3], the fatigue crack initiated from the scratch such as grinding one and grew as half ellipes. Here, the crack was assumed to be through crack to make parametoric analysis easy. The final crack size was set equal to 50 % width of main plate.

4. ANALYTICAL RESULTS

In order to examine the relations between the fatigue strength and the ratio of fillet radius (r) and width (d), fatigue strength at 2 millions cycles were calculated changing the ratio (r/d). Width of main plate, length of gusset and width are respectively 1 000 mm, 2 000 mm and 500 mm for the welded flange-gusset joint and 1 000 mm, 4 000 mm and 1 000 mm for the cut-off gusset joint. These sizes were determined considering the actual members of the Honshu-Shikoku Bridges.

In Fig. 6 and Fig. 7, the calculated results are shown and compared with the new design code[4] and the old one[1] for the Honshu-Shikoku Bridges, and the old one[2] and the new one[6] for Japanese National Railways. For the welded flange-gusset, in the region where r/d is smaller, the allowable stress in the both of old design codes for Honshu-Shikoku bridges and Japanese Railways is not conservtive. In the new design code for Japanese National Railways, the safesy margin is little near $r/d=0.2$. The new design code for the Honshu-Shikoku Bridges provides a constnt safety margin to the analytical results. For the joint cut off from the base material, in the old design code of Honshu-Shikoku Bridges, there is excessive margin in the region where r/d is larger as shown in Fig. 7. In the old code for Japanese National Railways, the allowable stress is not conservative in the region where r/d is smaller. The two new design code provide a constant safety margin.

5. CONCLUDING REMARKS

The pricipal findings from the present study are as follows.

In a groove-welded flange-gusset joint with fillet radius and a joint cut off from the base material, the fatigue strength decreases as the fillet radius (that is, the ratio of fillet raduis and width (r/d)) decreases. The results of this study have been used as the basis for the revision of the design code for the Honshu-Shikoku Bridges in 1982. In this design code, the relations between category of joints and r/d are as follows :

In the groove-welded flange-gusset joint with fillet radius

$r/d \geqq 1/3$ category B (124 MPa at 2 millions cycles)
$1/3 > r/d \geqq 1/6$ category C (103 MPa)
$1/6 > r/d \geqq 1/10$ category D (78 MPa)

In the joint cut off from the base material

$r/d \geqq 1/5$ category A (150 MPa)
$1/5 > r/d \geqq 1/10$ category B (124 MPa)

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