FATIGUE BEHAVIOUR OF WEB PENETRATION DETAILS WITH A SLIT IN STEEL GIRDER

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Abstract: Fatigue cracking in steel girder web penetration details is so dangerous that it can break steel girders. One-meter-long crack was detected in Yamazoe Bridge in 2006. Since a number of highway bridges with such web penetration details may exist in Japan, it is of urgent importance to grasp these fatigue strength properties. However, few fatigue tests have been reported on steel girder web penetration details. The purpose of this study is to clarify fatigue behaviour of steel girder web penetration details with a slit through fatigue tests of specimens which have steel girder web penetration details with a slit. We design and fabricate girder specimens which have steel girder web penetration details in which cross beam lower flanges are connected to each upper or lower surface of a slit by welding. First, we conduct static loading tests to grasp the stress distributions around web penetration details. Secondly, we conduct fatigue tests to examine fatigue crack initiation and propagation behaviour and fatigue strength.

Keywords: fatigue test, steel girder, web penetration, slit, crack, welded joint.

1. Introduction

Fatigue cracking in steel girder web penetration details is so dangerous that it can break steel girders. One-meter-long crack was detected in Yamazoe Bridge in 2006 [1]. Since a number of highway bridges with such web penetration details may exist in Japan, it is of urgent importance to grasp these fatigue strength properties. However, few fatigue tests have been reported on steel girder web penetration details [2, 3]. The purpose of this study is to clarify fatigue behaviour of steel girder web penetration details with a slit through fatigue tests of specimens which have steel girder web penetration details with a slit.

2. Test method

2.1. Specimen

We designed and fabricated 2-type steel girder specimens with web penetration details where a cross beam lower flange was connected to each upper or lower surface of a slit by fillet welding. Figure 1 shows configurations and dimensions of a specimen with a cross beam lower flange connected to the upper surface of the slit, and the location of strain gauges. The specimen has a slit in the lower center of steel girder web. The material is JIS 490YA steel. Submerged arc welding was used to connect web and flanges, while CO_2 arc welding was used to connect the other members. Table 1 shows the mill sheet of steel plates used in the specimen.

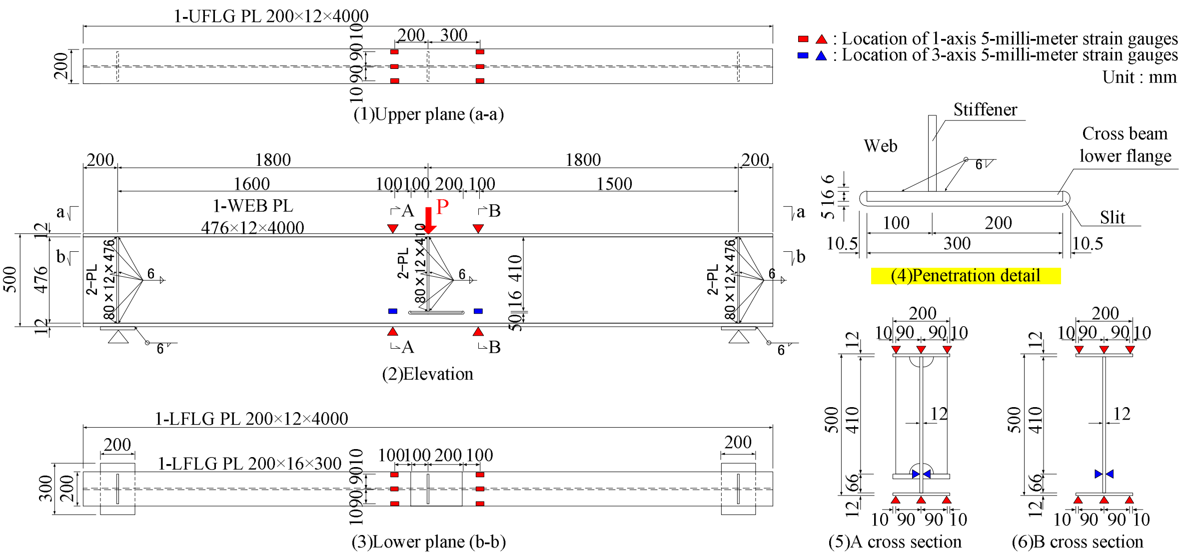


Fig. 1. Configurations and dimensions of specimen and location of strain gauges

Table 1. The mill sheet of specimen

Member	Material	Plate thickness (mm)	Tensile test			Chemical composition(%)				
			Y.S. [MPa]	T.S. [MPa]	EL [%]	C ×100	Si ×100	Mn ×100	P ×1000	S ×1000
Cross beam bottom flange	SM490YA	16	473	577	21	17	20	108	22	5
Top flange Bottom flange Web Sole plate Stiffener	SM490YATMC	12	393	519	28	16	19	110	15	2
Spec	MIN MAX	-	365 -	490 610	15 -	- 20	- 55	- 165	- 35	- 35

Standard: JIS G3106

2.2. Static loading test

First, we conducted static loading test in 3-point bending condition to grasp the stress distributions around web penetration details. 3-axis strain gauges were pasted on both surfaces of the web plate horizontally 100 mm away from cross beam lower flange edges to avoid the influence of the stress concentration near the welded joint. Three 1-axis strain gauges were pasted on the upper surface of upper flange and the lower surface of lower flange in the cross section where 3-axis strain gauges were pasted. The test load was set to 100 kN so that the maximum tensile stress of about 50 MPa might be generated in the lower flange considering the live-load stress.

2.3. Fatigue test

Fatigue test was conducted in 3-point bending condition as static loading test to clarify fatigue cracking behaviour and fatigue strength. The loading frequency was 6 Hz. The load range was set to be 100 kN, with the maximum load of 300 kN and the minimum load of 200 kN, considering the dead-load stress. In the case of a fatigue crack was propagated in one of two tested area, a stop hole was drilled and a high strength bolt was tightened to continue fatigue tests. Eddy Current Test (ET) and Magnetic Particle Test (MT) were applied to detect fatigue cracks at weld toe along cross beam lower flange edges.

3. Test results

3.1. Static Loading Test Results

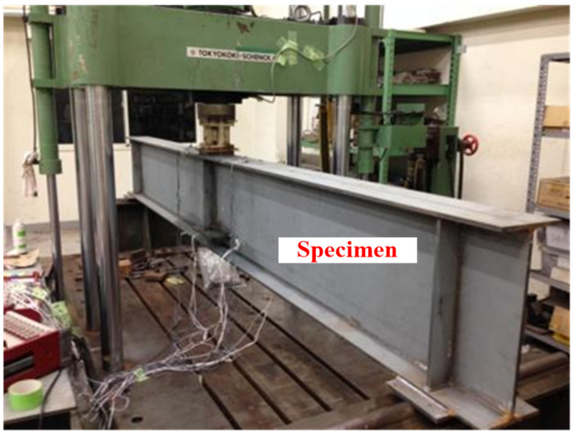


Photo 1. Loading test set up

Photo 1 shows loading test set up, Figure 2 shows bending stress distribution in the direction of girder depth, Figure 3 shows principal stress distributions around web penetration details. Nominal stresses were obtained from bending moment and shearing force calculated according to the beam theory neglecting the cross beam lower flange and stiffeners. It was confirmed that the measured maximum principal stresses nearly equal to the calculated values, although the measured value was about 2～6% larger than the calculated one.

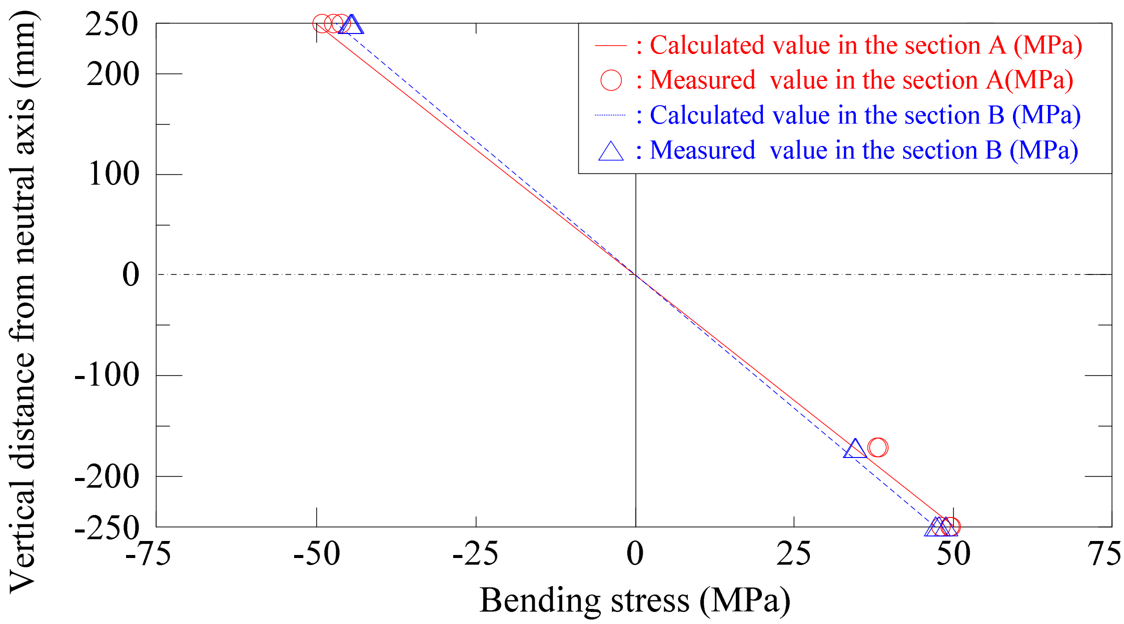


Fig. 2. Bending stress distribution in the direction of girder depth

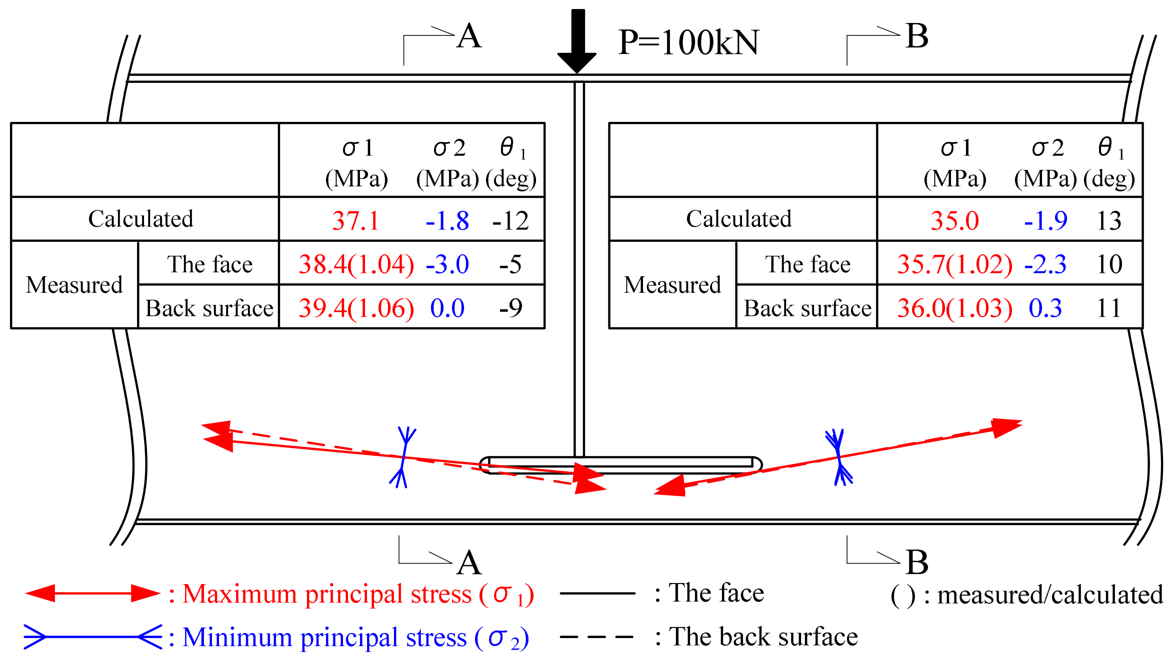


Fig. 3. Principal stress distributions around web penetration details

3.2. Fatigue test results

Figure 4 shows relationship between the fatigue crack length and the number of loading cycles. Cracks with the length of 8mm were detected at four web-side toes of the fillet welds along cross beam lower flange edges at 0.2 million cycles. Fatigue cracks were propagated into the web plate on both surfaces in the section A at 0.8 million cycles, on the face in the section B at 1.2 million cycles and on the back surface in the section B at 2.3 million cycles. As the crack in the section A was growing, the crack in the section B was growing slowly because the load could not be carried to the section B.

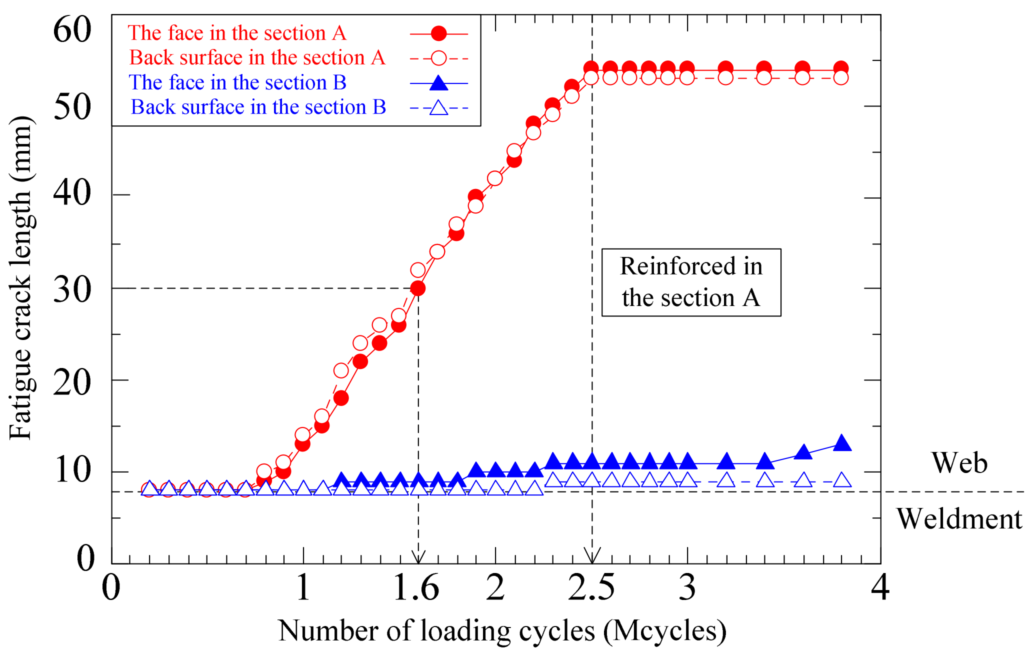


Fig. 4. Relationship between fatigue crack length and number of loading cycles

Photo 2 shows a fatigue crack propagated to the length of 54mm at 2.5 million cycles. The cracks were propagated into the web plate almost perpendicularly to the maximum principal stress direction.

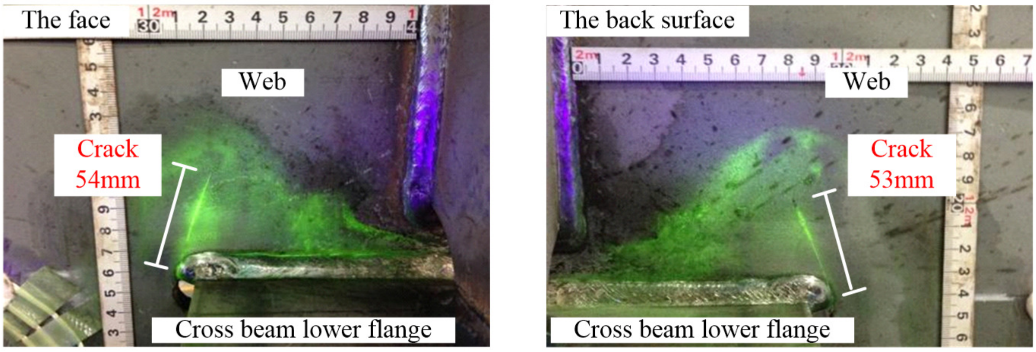
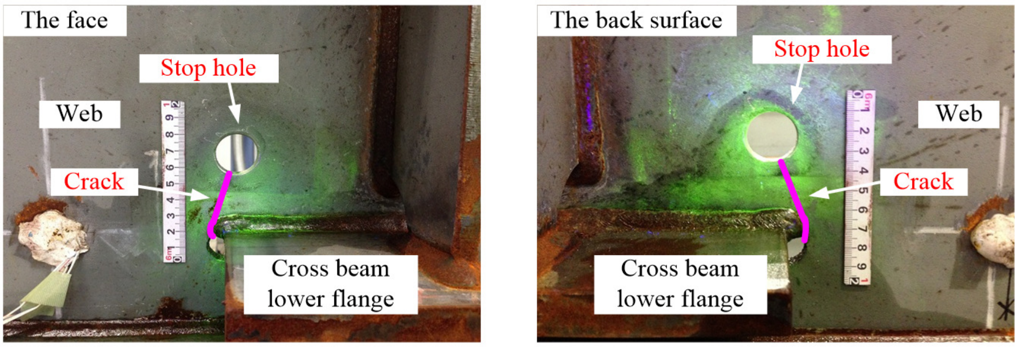
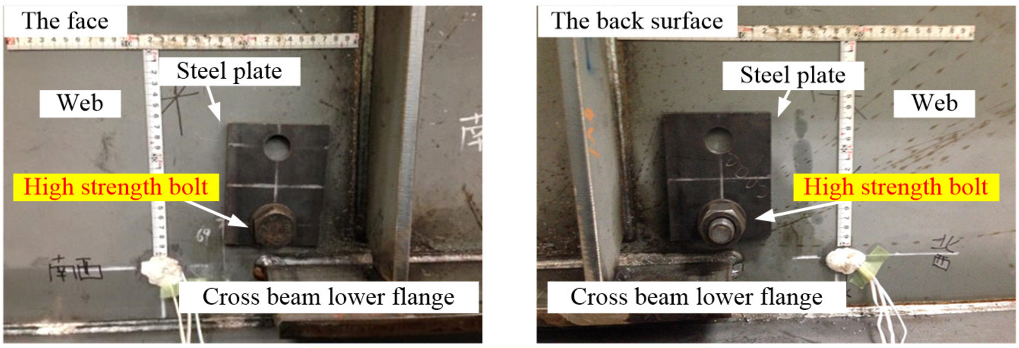


Photo 2. Fatigue crack in the section A at 2.5 million cycles

Photo 3 shows a stop hole and a high strength bolt. A stop hole was drilled and a high strength bolt was tightened in order to stop fatigue crack propagation in the section A at 2.5 million cycles.



(1)A stop hole



(2)A high strength bolt

Photo 3. A stop hole and a high strength bolt in the section A

Figure 5 shows the relationship between principal stress range and fatigue life of the specimen. Figure 6 shows the relationship between bending stress range and fatigue life of the specimen. Fatigue life when the crack is detected at web-side toes of the fillet welds along cross beam lower flange edges (Nd) is 1/6 ～1/4 of class H' (the lowest fatigue class in Japanese Specifications for Highway Bridges [4]), fatigue life when the crack is propagated into the web plate (N_w) is less than class H', and fatigue life when the crack length reaches 30 mm (N_{30}) satisfies class H'.

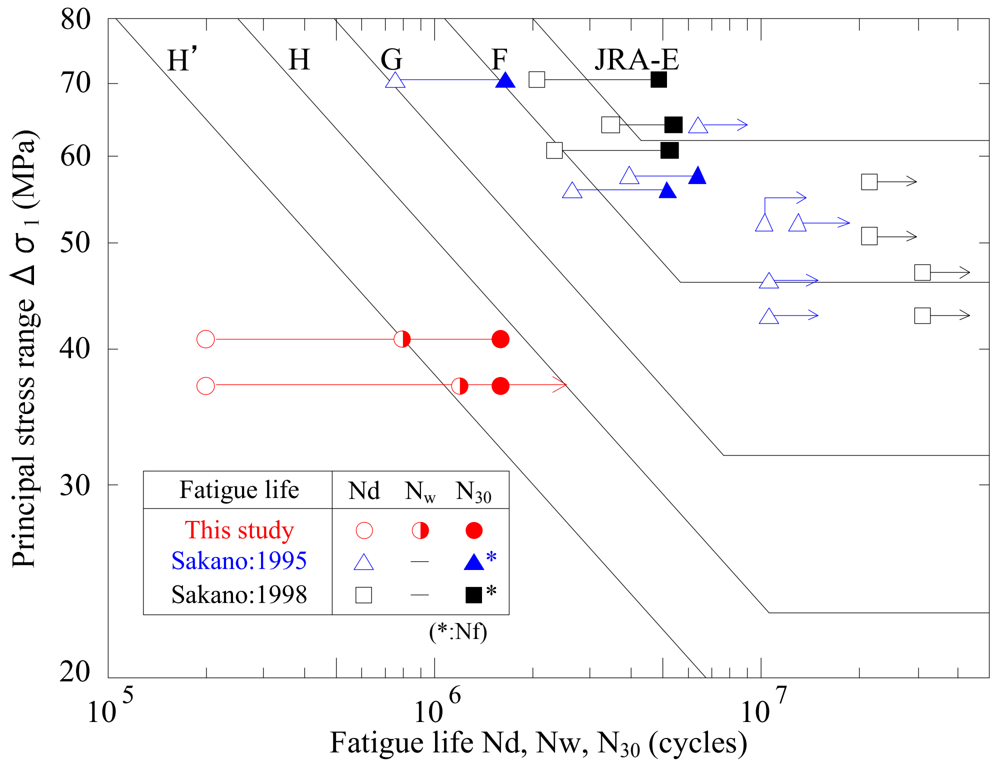


Fig. 5. Fatigue life of the specimen (Principal stress range)

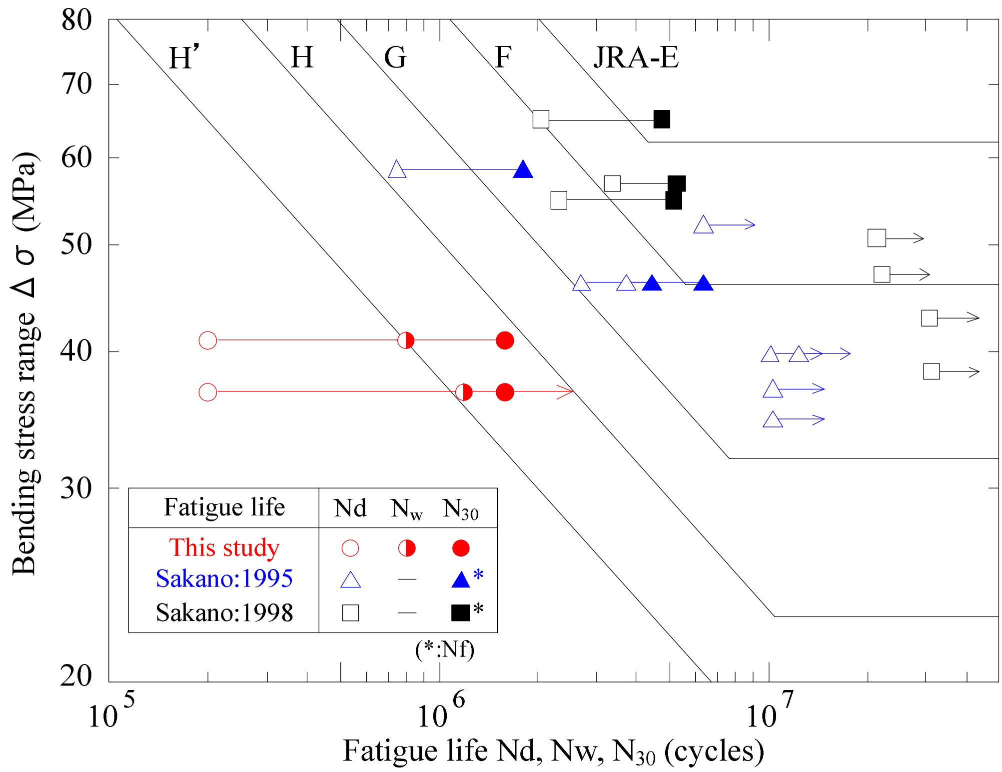


Fig. 6. Fatigue life of the specimen (Bending stress range)

4. Conculusion

The principal results obtained through this study are as follows;

1. Fatigue cracks were initiated at the web-side toe of the fillet weld along cross beam lower flange edges, and propagated into the web plate almost perpendicularly to the maximum principal stress direction.
2. Fatigue crack detection life is 1/6 ～ 1/4 of class H’, fatigue life when the crack has been propagated into the web plate is less than class H’, and fatigue life when the crack length reaches 30mm satisfies class H’.

References

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