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FATIGUE TEST OF STEEL GIRDER WEB PENETRATION DETAILS WITH A SLIT

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Fatigue cracking in steel girder web penetration details is so dangerous that it can break steel girders. A 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 understand 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 behavior of steel girder web penetration details with a slit through fatigue tests of specimens with these details. We designed and fabricated girder specimens that have steel girder web penetration details, in which cross-beam bottom flanges are connected to each top or bottom surface of a slit by welding. First, we conducted static loading tests to understand the stress distributions around web penetration details. Second, we conducted fatigue tests to examine fatigue crack initiation and propagation behavior 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. A one-meter-long crack was detected in Yamazoe Bridge in 2006 (Nara National Highway Homepage 2014). Since a number of highway bridges with such web penetration details may exist in Japan, it is of urgent importance to understand these fatigue strength properties. However, few fatigue tests have been reported on steel girder web penetration details (Sakano et al. 1995, 1998). The purpose of this study is to clarify fatigue behavior of steel girder web penetration details with a slit through fatigue tests of specimens that 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 bottom flange was connected to each top or bottom surface of a slit by fillet welding. Figure 1 shows configurations and dimensions of a specimen with a cross-beam bottom flange connected to the top surface of the slit, and the location of strain gauges.

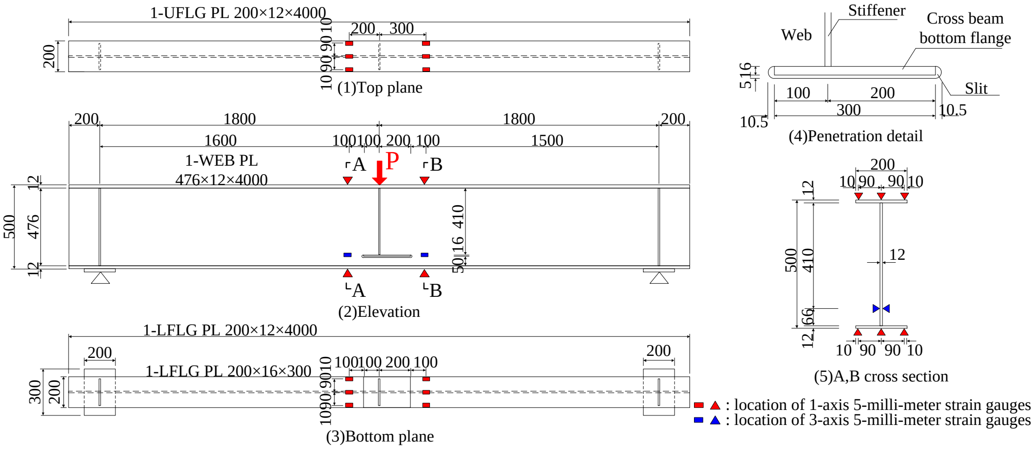


Figure 1. Configurations and dimensions of specimen and location of strain gauges.

Table 1. The mill sheet of specimens.

Member	Plate thickness (mm)	Mechanical properties			Chemical composition(%)					
		Y.P. (MPa)	T.S. (MPa)	EL (%)	C ×100	Si ×100	Mn ×100	P ×1000	S ×1000	Ceq.1 ×1000 Ceq.2 ×1000
Cross beam bottom flange	16	436	543	26	16	41	140	15	6	41 —
Upper flange	12	451	554	22	15	20	117	13	2	22 36
Lower flange Web Sole plate Stiffener	12	407	523	24	15	19	115	18	5	22 35
Spec	MIN MAX	365 —	490 610	15 —	— 20	— 55	— 165	— 35	— 35	— 26

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.

2.2 Static Loading Test

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

2.3 Fatigue Test

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

3 Test Results

3.1 Static Loading Test Results

Photo 1 shows the 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 moments, and shearing force was calculated according to beam theory, neglecting the cross-beam bottom flange and stiffeners. It was confirmed that the measured maximum principal stresses were nearly equal to the calculated values, although the measured value was about 2-6% larger than the calculated one.

Photo 1. Loading test set up.

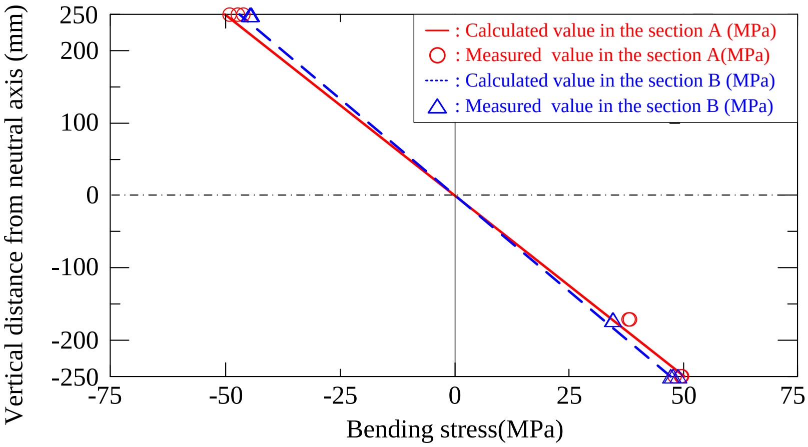
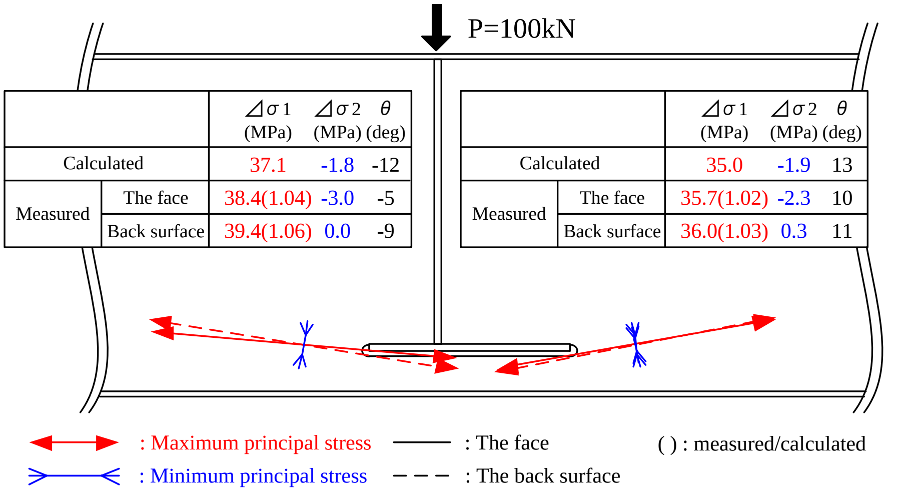


Figure 2. Bending-stress distribution in the direction of girder depth.



		⊿σ1 (MPa)	⊿σ2 (MPa)	θ (deg)
Calculated		37.1	-1.8	-12
Measured	The face	38.4(1.04)	-3.0	-5
	Back surface	39.4(1.06)	0.0	-9

		⊿σ1 (MPa)	⊿σ2 (MPa)	θ (deg)
Calculated		35.0	-1.9	13
Measured	The face	35.7(1.02)	-2.3	10
	Back surface	36.0(1.03)	0.3	11

Figure 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 the cross-beam bottom flange edges at 0.2 million cycles. Fatigue cracks were propagated into the web plate on both surfaces in section A at 0.8 million cycles, on the face in section B at 1.2 million cycles, and on the back surface in section B at 2.3 million cycles. As the crack in section A grew, the crack in section B was growing slowly because the load could not be carried to section B.

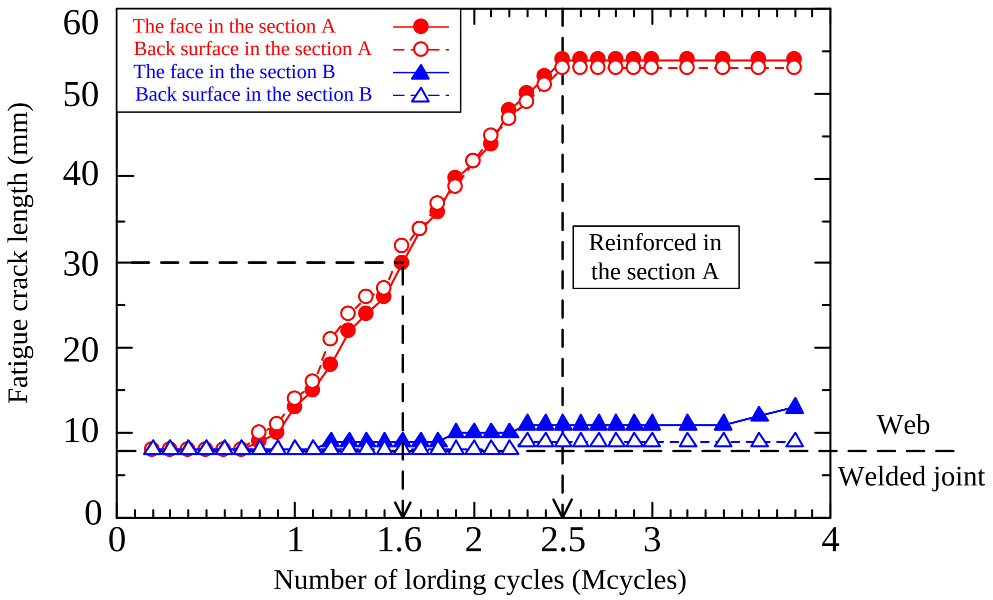


Figure 4. Relationship between fatigue crack length and number of loading cycles.

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.

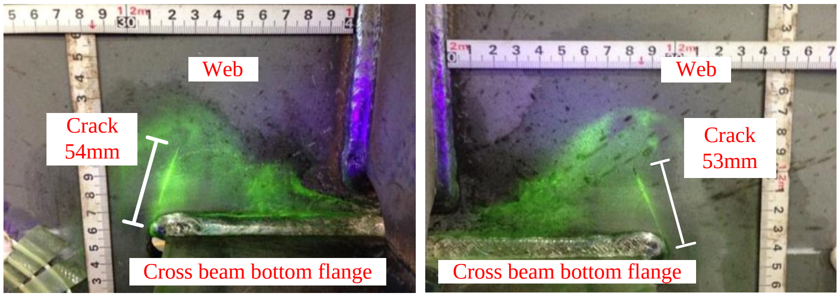
Photo 3 shows a stop hole and a high-tension bolt. A stop hole was drilled and a high-tension bolt was tightened in order to stop fatigue crack propagation in section A at 2.5 million cycles.

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 the fatigue life of the specimen. Fatigue-crack detection life (Nd) is 1/6 ～1/4 of class H'. 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 30mm (N_{30}) satisfies class H'.

4 CONCLUSIONS

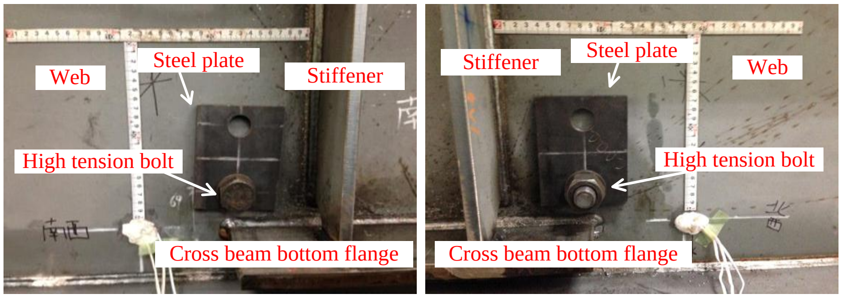
(1) Fatigue cracks were initiated at the web-side toe of the fillet weld along cross-beam bottom flange edges, and propagated into the web plate almost perpendicularly to the maximum principal stress direction.

(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'.



(1)The face in the section A (2)The back surface in the section A

Photo 2. Fatigue crack at 2.5 million cycles.



(1)The face in the section A (2)The back surface in the section A

Photo 3. A stop hole and a high tension bolt.

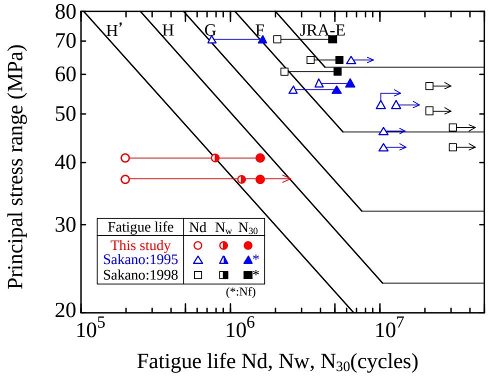


Figure 5. Fatigue life of the specimen (Principal stress range).

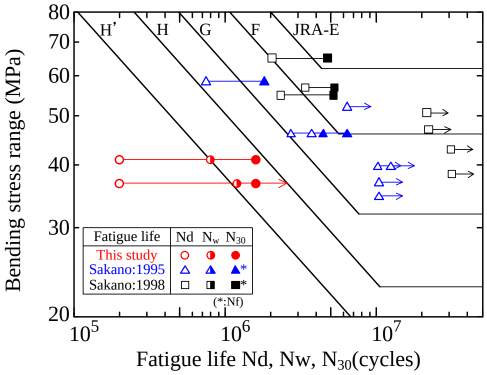


Figure 6. Fatigue life of the specimen (Bending stress range).

References

Nara National Highway Homepage, 2014 (in Japanese), downloaded from http://www.kkr.mlit.go.jp/nara/.

Sakano, M., Hozumi, M., Shimori, T., and Mikami, S., Long-term fatigue strength of web gusset joint in floor-beam-to-main-girder connection, *Steel Construction Engineering*, (5)18, 31-40, 1998 (in Japanese).

Sakano, M., Mikami, I, Murayama, H., and Moriwaki, K., Fatigue strength of railway plate girder with web penetration, *Journal of Structural Engineering*, 41A, 965-973, 1995.