EFFECT OF STRENGTH MATCHING ON LOW CYCLE FATIGUE PERFORMANCE OF LOAD CARRYING CRUCIFORM JOINTS WITH WELD DEFECTS

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1. INTRODUCTION

Steel bridge bents are widely used in elevated highway. At the welded joints in beam to column connection of steel bridge bents, full penetration weld joints have been required due to high level of load transfers through its connected parts. However, the survey by Miki et al was found that most of existing beam to column connections have partial penetration weld joints[1]. Moreover, steel bridge bents are widely made of high strength steel and the strength of weld metal are often lower than that of base metal which cause under-matching issues. In low cycle fatigue region, the behaviors of the joints are differing by strength matching since plastic deformation dominates in lower strength materials.

2. EXPERIMENTAL METHODS

(2.1) Fabricating and preparation of specimens

Types, configurations and dimensions of specimen are shown in **Fig.1** and **Table.1**. Five welding materials were used to fabricate the specimens.

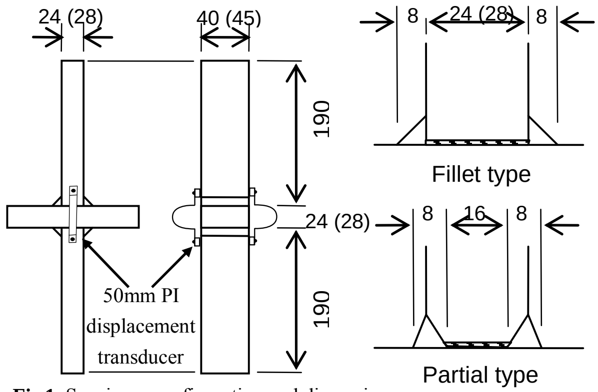


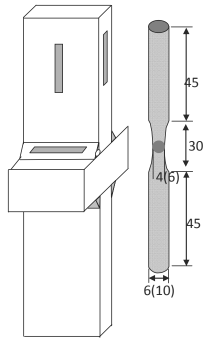
Fig.1. Specimen configuration and dimensions

Table.1. Types and specifications of specimens.

Base metal	**490 MPa class steel**						**BHS500**	
Weld metal	A		B		C		D	E
Thickness(mm)	28	28	28	28	28	28	24	24
Width(mm)	45	40	45	40	45	40	40	40
Specimen	FA	PA	FB	FB	FC	PC	FD	FE

(2.2) Material test

Fig.2 shows Mechanical properties of material which were obtained by tensile test. Specimen for base metal was cut out from the loading plate and for deposit metal was machined from welding part as shown in **Fig.2**. Yield stress of weld material from certificate and tensile test were different. Generally, yield stress of weld metal was considered from strength of metal used to make electrode. However, during the welding process, mixing between base and weld metal and cooling rate can effect the strength of weld deposit. Thus, the strength of weld metal and weld deposit were different as shown in the table in **Fig.2**



Material		As certificate	Actual tensile test	
		Yield stress (MPa)	Yield stress (MPa)	Ratio of yield stresses (WD/BM)
490MPa(BM)			392	–
Weld deposit (WD)	A	430	498	1.27
	B	438	494	1.24
	C	489	565	1.44
BHS500(BM)			554	-
Weld deposit (WD)	D	449	491	0.89
	E	426	451	0.81

Fig.2 Specimen used for material testing (Number in the bracket is base material) (Dimension in mm) and Mechanical properties of materials

(2.3) Low cycle fatigue test

Low cycle fatigue tests were controlled with the value of displacement transducer attached at both side of specimen giving various the displacement ranges. Cyclic load with very low loading rate was applied to the specimen. After one weld bead was penetrated by cracking, the specimen was loaded monotonically to break completely.

(2.4)Tensile and high cycle fatigue test

Tensile and high cycle fatigue test were conducted in comparison. Nominal stress applied to high cycle fatigue tests was obtained by dividing the load range by the actual weld throat area which were 140 to 180MPa.

3. EXPERIMENTAL RESULTS

(3.1) Load-displacement relationship

Fig.3 (a) shows an example of the load-displacement relationship in the low cycle fatigue test. **Fig.3 (b)** represents fully cyclic test plotting with tensile test results of weld material A. Hysteretic curve of cyclic test has higher stress than tensile and cyclic hardening can be observed. However, from **Fig.3 (a)** load decreases during the cyclic repetition. It

Key Words: load carrying cruciform joint, incomplete penetration, matching, crack propagation direction

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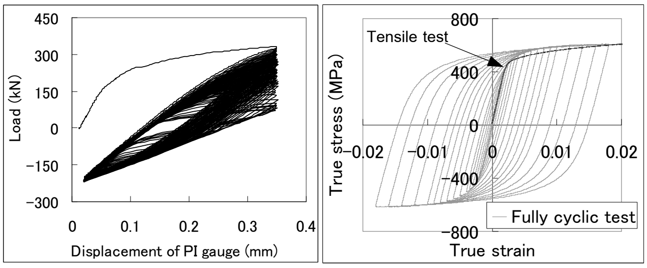
can be said that crack initiates since first few cycles. Thus, crack propagation is predominant in low cycle fatigue region

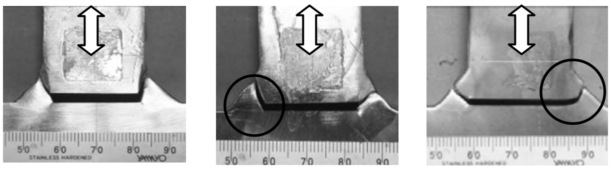


(a) **(b)**

Fig.3 **(a)** Load-displacement relationship (specimen FA) / **(b)** cyclic hardening behavior (weld material A)

(3.2) Crack Propagation Path

Side surfaces of the ruptured specimens are shown in **Fig.4**. Cracks initiated from weld root and propagated to deposit metal. **Fig.5** shows relationship between failure angles and fatigue life, for low cycle fatigue results, fatigue life was referred to number of cycle to 30% load drop. For high cycle fatigue results, fatigue life was referred to number of cycle to complete rupture. Failure angles were measured from mid-width of specimen. In the same weld metal, failure angle became smaller when fatigue life decrease. Moreover, failure angle became smaller when ratio of yield stress of weld deposit to base material decreased.



(a) Tensile (b) Low cycle fatigue (c) High cycle fatigue

Fig.4 Crack propagation of each test (Circles indicated failure from fatigue crack) (Arrow indicated loading direction) (specimen FA)

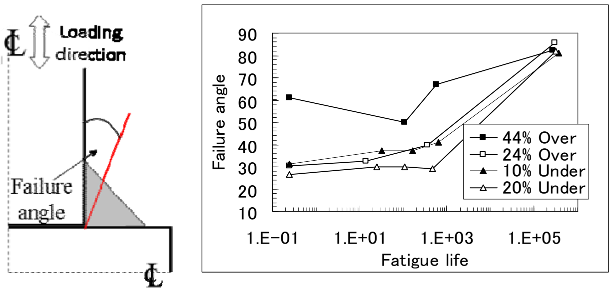
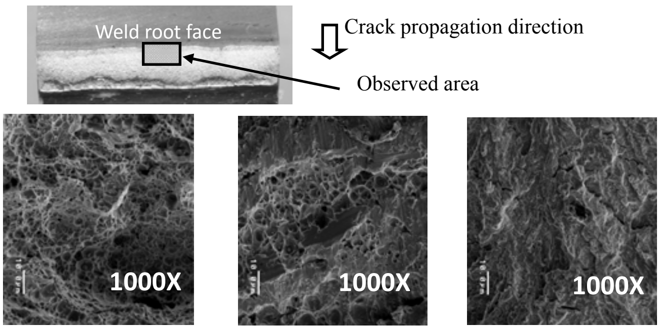


Fig.5 Relationship between failure angle and number of cycles



(a) Tensile (b) Low cycle fatigue (c) High cycle fatigue

Fig.6 Fractography (specimen FA)

(3.3) Fractography

Fig.6 shows fractographs taken close to the weld root around the mid-width of the specimens. The crack initiated from the weld root and propagated into the weld metal. The weld root is located at the upper side of the picture and the crack penetrates downward. The fractograph of tensile and low cycle fatigue test show dimple and mashed dimples[2]. Thus, the ductile crack propagation is predominant in low cycle fatigue region.

(3.4) Fatigue Life

Fig.7 shows the relationship between nominal strain range and number of cycle. The strain range was calculated from displacement of PI displacement transducer divided by gauge length. The results show specimens with lower ratio of yield stress of weld deposit to meld material tend to have lower fatigue life. Even though, the effect of matching in high cycle fatigue region was small. The effect of matching became important in low cycle fatigue region. As a result, special care should be given in order to prevent failure of the weld joints in beam to column connections.

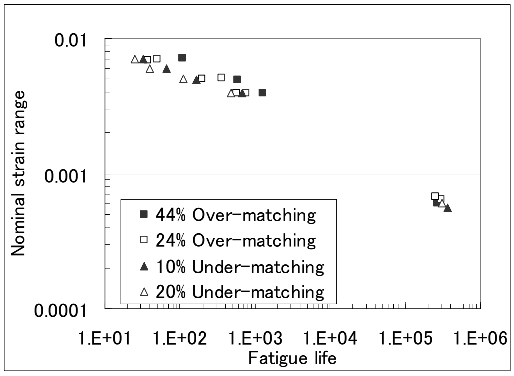


Fig.7 Relationship between nominal stress range and fatigue life

4. CONCLUSIONS

1.) Crack initiation point located at the weld root in the mid-width of the specimen. Then, the crack propagated through the weld deposit.

2.) For low cycle fatigue specimens, crack initiates and propagates since first few cycles.

3.) Observations by SEM revealed that ductile crack propagation is predominant in low cycle fatigue region.

4.) Failure angle can be related to fatigue life.

5.) In low cycle fatigue region, higher fatigue life can be observed when ratio of yield stress of weld deposit to base material increases.

5. REFERENCES

1.) Miki, C. (2007): *Doboku Gakkai Ronbunshuu A*, JSCE, **63**(3), 518-532.

2.) Kuwamura, H. (1997): *Journal of structural engineering*, ASCE, **123**, 864-870