Tensile and Fatigue Properties of Large Structural Members by a Newly Developed Welding System †

KIM You-Chul *, OKU Kentaro **, UMEKUNI Akira *** and HORIKAWA Kohsuke****

Abstract

In the civil engineering and architecture fields, welding of large sectional members, such as I section and H section steels, are usually required. A flash welding system, by which large I section steel or H section steel can be welded for a short time, was newly developed to shorten the joining time of large sectional members.

The joining time of rolled SS400 H section steel (300 ×300 ×10 ×12 ((mm)) was about 5 minutes (Joining time was 1/10 compared with that of arc welding).

From the results of tensile tests, the joint efficiency of welded joints by the newly developed flash welding system was 100% for the specimens with reinforcements and 93% without reinforcements. In fatigue tests, the fatigue strength of welded joints with reinforcements was about 50% of that of the base metal. By removing the reinforcement naturally generated by flash welding, the fatigue strength of flash welded joints became 75% of that of the base metal. In fatigue design, flash welded joints with reinforcement had the same grade of fatigue strength as the non-load-carrying fillet joints by arc welding.

KEY WORDS: (Flash Welding), (Tensile Strength), (Fatigue Strength), (H Section Steels)

1. Introduction

Large sectional members such as I section steel, H section steel and pipes are very often joined in construction works. However, long execution times are required to join these large sectional members by welding or high strength bolts. A flash welding system for construction site welding was newly developed to shorten the joining time of large sectional members [1)].

If flash welding is performed in general, reinforcements (upset metals) are inevitably generated in the joints. The reinforcements become a source of stress concentration, and cause adverse effects on the mechanical properties of the joints. In general, reinforcements are removed. However, long times are required to remove reinforcements.

In this study, in order to use the structural members without removing reinforcements, tensile test and fatigue test for welded joints by the newly developed flash welding system are carried out. From the experimental results, the mechanical characteristics of welded joints are investigated.

2. Experiments

2.1 Material and specimen

The H section steel used in the experiment is a rolled structural steel (300×300×10×12 ((mm)). The material is SS400 (A36 in USA). The joining time of the rolled H section steel is about 5 minutes (Joining time was 1/10 compared with that of arc welding).

The tensile specimens are cut from the joints of the webs. The welds were located at the center of the specimens. **Figure 1** shows the shapes of each specimen. Specimens used in the experiments are as follows:

Base metal (with surface as forged): BM
Welded joint with reinforcement: WJ-1W
Welded joint without reinforcement: WJ-2W

2.2 Tensile test

The gauge length of the specimens was 50 mm, and strain gauges are attached between the gauge marks. The welds of the specimen are etched to reveal the bond line. By observation of the macrograph, the exact location of the fractured point is determined.

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* Professor
** Graduate Student
*** Takenaka CO.
**** Professor Emeritus
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2.3 Fatigue test

The fatigue tests are carried out under the loading conditions of pulsating tension by using a single axis fatigue test machine. The shape of waves is sine waves with a frequency of 5-10 (Hz).

Specimens of welded joints are cut from the web, and the fatigue tests are conducted. Some specimens of base metal are fractured at their gripped parts. Therefore, only for the base metal, specimens whose width is 10mm wider than that of WJ-series specimens in grip sections are used.

3. Results and Discussions

3.1 Tensile properties

Table 1 shows the tensile test results of BM, WJ-1W and WJ-2W. The yield stress of WJ-2W, 0.2% proof stress is used.

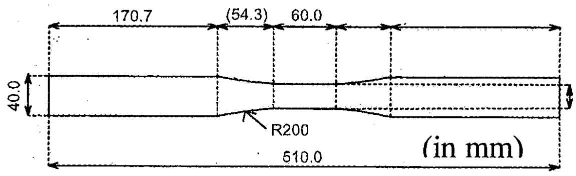
WJ-1W specimens break in a ductile manner in the base metal. The yield stress and tensile strength of WJ-1W are the same level as those of the base metal, however the elongation at the maximum load and fractured load is smaller than those of the base metal. The reason why the elongation is smaller is that the thickness of welds with upset metals is thicker than that of the base metal. So, welds are not deformed uniformly.

On the other hand, in all specimens of WJ-2W, brittle fractures occur at the bond lines. The yield stress, tensile strength and elongation of WJ-2W are lower than those of the base metal. The joint efficiency is about 93% in this experiment. The fractures occur at the base metals for flash welded specimens without reinforcements under tensile tests. Therefore, it is thought that the joints should be used without removing reinforcements from the viewpoint of tensile strength.

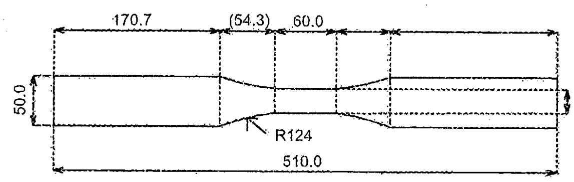
3.2 Fatigue properties

Figure 2 shows the fatigue test results of the base metal (BM), welded joints with reinforcement (WJ-1W) and welded joints without reinforcement (WJ-2W). The fatigue strengths of BM, WJ-1W and WJ-2W at 2x106 cycles are 366.0, 179.0 and 275.0 (MPa) respectively, and the fatigue strength of WJ-1W is about 50% of that of BM and the fatigue strength of WJ-2W was 75% of that of BM. It is natural that a welded joint without reinforcement is more dominant than a welded joint with reinforcement.

In WJ-1W specimens, after a couple of fatigue cracks propagate, ductile fracture occurs at the toe of the



(a) WJ-series specimens (Welded joints).



(b) Specimen of base metal.

Fig. 1 Tests specimens.

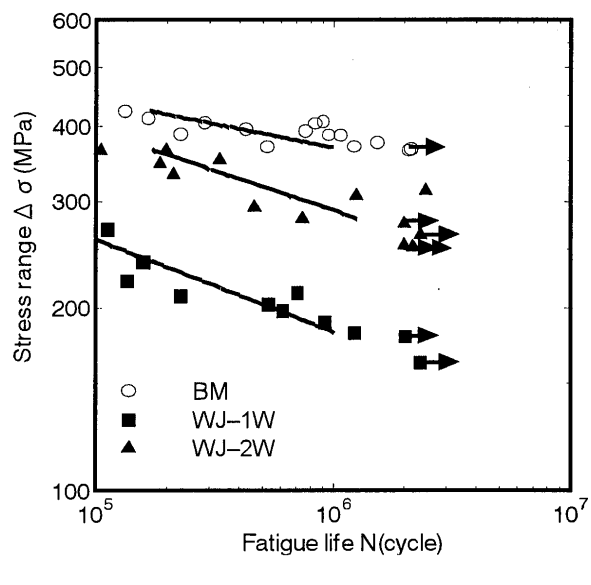


Fig.2 Results of fatigue test.

Table 1 Results of tensile test.

Series	Yield stress (MPa)	Tensile strength (MPa)	Elongation (%)
BM	348.1	468.3	37.9
WJ-1W	341.3	476.6	28.8
WJ-2W	253.6	435.9	22.0

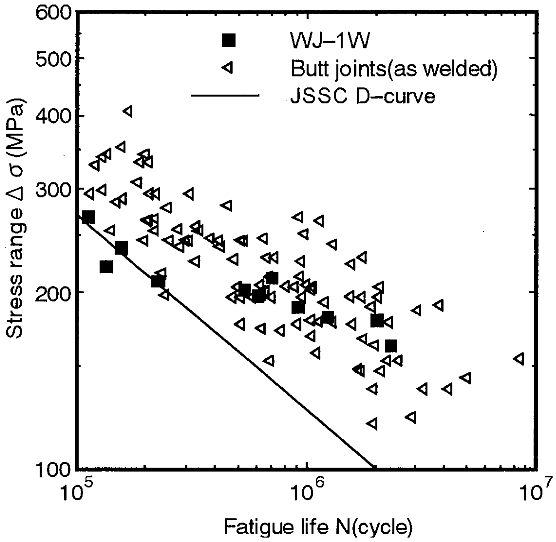


Fig.3 Experimental results for WJ-1W and arc welded butt joints with reinforcement.

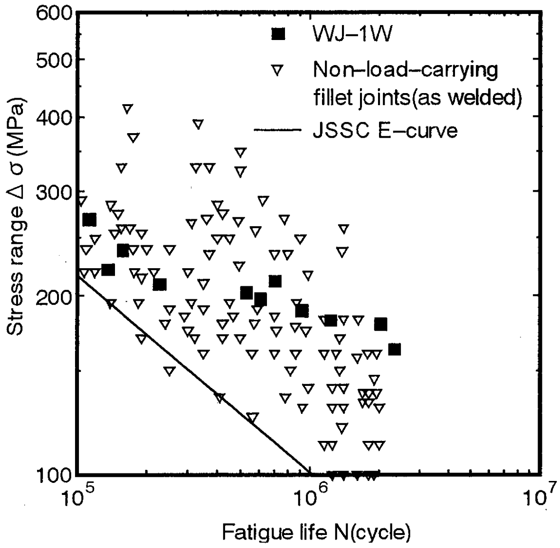


Fig.4 Experiment results for WJ-1W and the non-load-carrying fillet joints.

reinforcement. The reason why the scattering of the experimental results is small is that the shapes of reinforcements are almost the same in flash welding. In WJ-2W specimens, fractures occur in the HAZ from 10 mm or less from the bond. In the case that a couple of fatigue cracks propagate at the bond, fracture is brittle. In the case that a couple of fatigue cracks propagate in the HAZ, fracture is ductile. The reason why the scattering of the experimental results of WJ-2W is large is that the irregularity of the joints influences the results of the fatigue test.

As generally known, the fatigue strength of welded joints with reinforcement is greatly influenced by the shapes of reinforcement. In the case of no reinforcement, fatigue strength is greatly influenced by the irregularity.

3.3 Fatigue grades of flash welded joints

Fatigue grades of flash welded joints with reinforcement in fatigue design are investigated comparing with the fatigue strength of conventional arc welded joints.

Figure 3 shows the fatigue tests results of welded joints with reinforcement. The results of fatigue tests of arc welded butt joints from past data and the design stress range curve of the guideline and commentary of fatigue design of steel structures by JSSC (Japanese Society of Steel Construction) are shown in the same figure.

The fatigue grade requiring arc welded butt joints with reinforcement is D-grade ($\Delta\sigma_f$=100 (MPa)). The experimental results of WJ-1 fall in the middle of the dispersion range of past data in the high fatigue life region (from $5x10^5$ to $2x10^6$ cycles). However the experimental results of WJ-1W become close to the lower limit of the past data in the low fatigue life region (from $1x10^5$ to $3x10^5$ cycles).

Figure 4 shows the fatigue test results of WJ-1W and the non-load-carrying fillet joints from past date with the design stress range curve of JSSC. The fatigue grade requiring non-load-carrying fillet joints is E-grade ($\Delta\sigma_f$=80 (MPa)) in JSSC. The experimental results of WJ-1 fall in the dispersion range of the experimental results regardless of the high fatigue life region or the low fatigue life region. This is because the shape of the toe in flash welding is similar to the toe in fillet welding rather than the toe in arc butt welding.

In any case, the fatigue strength of flash welded joints with reinforcement can be considered to be almost the same as that for the non-load-carrying fillet joints.

4. Conclusion

Newly developed flash welding system was used to join rolled H section steels.

(1) The joining time of the rolled H section steel (300×300×10×12 ((mm))is about 5 minutes (Joining time was 1/10 compared with that of arc welding).

Cutting out specimens from welded joints, a series of experiments were carried out.

(2) Tensile strengths of the welded joints with reinforcements had almost the same yield stress and tensile strength as those of the base metal. However, in case that reinforcement was removed, the yield stress and tensile strength of the joints decreased less than those of the base metal. Contrary to this, a welded joint with reinforcement

was more dominant than a welded joint without reinforcement from the viewpoint of tensile strength.

(3) Fatigue strength of flash welded joints with reinforcement was about 50% of that of the base metal. By removing the reinforcement generated by the flash welding, the fatigue strength of flash welded joints became 75% of that of the base metal.

Considering the fatigue design of joints welded by flash welding system,

(4) Flash welded joints with reinforcement had the same grade of fatigue strength as the non-load-carrying fillet joints by arc welding.

Reference

1) Welding News, Sanpou Publication, No.2426, and 2001/5/15 issues.