Mechanical Characteristics of Welds Joined by Newly Developed Welding Wire with a Phase Transformation at Low Temperature (II) †

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Abstract

A reduction in the consumption of energy for correction of welding distortion is demanded from the environmental and economical point of view. So, a welding consumable (welding wire), for which it is unnecessary to correct the welding distortion, was newly developed. Based on the mechanical properties of welds using an existing welding wire, the mechanical properties of welds using the newly developed welding wire were evaluated. Moreover, the structural soundness of welds was evaluated from the characteristics of structures produced by each welding wire. Despite the fact that the mechanical characteristics of the newly developed welding wire were a little inferior to an existing welding wire, it does not present much of a problem to practical use from the overall point of view

KEYWORDS: (Phase transformation) (Welded joints) (Soundness) (Fatigue test) (Compressive test)

1. Introduction

In the fabrication of steel structures, the correction of distortion generated by welding needs plenty of energy. A reduction in the consumption of energy for correction of welding distortion is demanded from the environmental and economical point of view. The distortion generated by welding can be decreased using a high strength steel. But, that affects the production cost, and, the distortion generated by welding can be decreased by using a wire, in which more Mn is included. There are several selections for the reduction of welding distortion like this. The welding consumable is considered among several selections and this is specially considered from the economical point of view. Therefore, a welding consumable (welding wire), in which it is unnecessary to correct the welding distortion, is newly developed.

In this paper, the mechanical properties and the soundness of welds jointed by using this newly developed welding wire are evaluated as compared with those of welds jointed by an existing welding wire.

2. Experiment

It is generally known that the transformation temperature has an effect on welding distortion. In order to develop a welding wire with little distortion, the transformation temperature is controlled through the regulation of Cr and Ni. The chemical ingredients of the newly developed welding wire are shown in **Table 1**, and, its mechanical properties are shown in **Table 2**. It has high tensile strength in comparison with existing wire. The welding is carried out without preheating and postheating.

Table 1 Chemical composition of newly developed welding wire.

Welding wire	Chemical composition (%)								
	C	Si	Mn	P	S	Ni	Cr	N	O
1.2mm ϕ	0.057	0.49	1.71	0.008	0.005	3.00	12.10	0.006	0.090
1.4mm ϕ	0.058	0.40	1.67	0.007	0.003	3.26	11.97	0.005	0.080

Table 2 Mechanical properties of newly developed welding wire.

Welding wire	Tensile properties				Impact property
	Yield stress (MPa)	Tensile strength (MPa)	Elongation (%)	Reduction of area (%)	Absorbed energy (J)
1.2mm ϕ	1180	1130	10	25	18
1.4mm ϕ	1070	1126	9	18	20

† Received on December 14, 2007.

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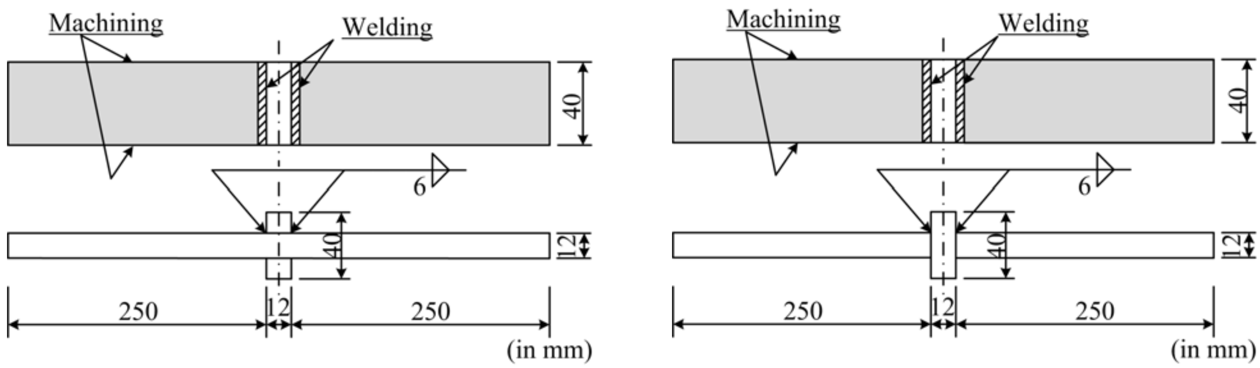
Table 3 Welding conditions for small-sized fatigue test specimen and plane-panel fatigue test specimen.

Wire	Experiment	Pass	Current(A)	Voltage(V)	Velocity (cpm)	Method of welding
Existing wire	Small sized	4	290-310	32-33	30-35	100% Co_2 gas metal arc welding
	Plane panel	6	280	32	31-37	
Developed wire	Small sized	4	210-220	29-30	21-27	
	Plane panel	6	220	29	27-30	

Table 4 Welding conditions for box structure.

Wire	Current(A)	Voltage(V)	Velocity (cpm)	Method of welding
Existing wire	290-310	32-33	30-35	100% Co_2 gas metal arc welding
Developed wire	210-220	29-30	21-27	



(a) Non load-carrying type fatigue test specimen. (b) Load-carrying type fatigue test specimen.

Fig.1 Dimensions of small-sized fatigue test specimen.

2.1 Welding distortion

Test specimen and existing wire is SM490Y and MX-Z200 respectively. **Table 3** and **Table 4** shows the welding conditions for the fatigue test specimen and box structure.

After the manufacture of the test specimen (plane-panel test specimen and box structure) with these welding conditions, welding distortion was measured. The welding distortion with regard to each measuring point of the plane-panel test specimen is measured based on the line linking both sides of the specimen. In the box structure, the 3D deformation measuring system is used for measuring of welding distortion.

2.2 Fatigue tests of welded joints

2.2.1 Fatigue test of small-sized fatigue test specimen

Figure 1 shows the shape and dimensions of small-sized fatigue test specimens. It was decided to refer to shape and dimensions of the tensile test specimen.

2.2.2 Fatigue test of plane-panel test specimen

Figure 2 shows the shape and dimensions of a plane-panel fatigue test specimen and load condition. When the plane-panel fatigue test specimen is made by welding, out-of-plane distortion is generated inevitably. So, the 3-point bending fatigue test is carried out after the correction of the out-of-plane distortion generated by welding. The correction of out-of-plane distortion is performed only with a press.

The fatigue crack was detected by the field signature method[1]. The circle symbol of Figure 2 and **Figure 3** shows the positions of sensing pins for FSM.

2.3 Compressive test of box structure

Figure 4 shows the shape and dimensions of box structure for the compressive test. And **Figure 5** shows the state of the compressive test. The vertical and horizontal displacement is measured by a bar type displacement convertor. The displacement convertors for measuring vertical displacement are set at the upper flange of the test specimen. In order to check the displacement mode, the displacement convertors for measuring horizontal displacement are set at the four web sections as in Figure 4 and Figure 5. In order to check the balance of the applied load, the strain gauges are attached at the same place with bar type displacement convertors for measuring horizontal displacement.

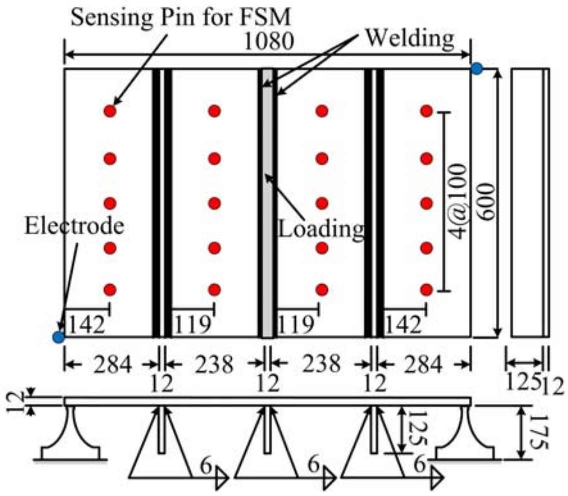


Fig.2 Dimensions of plane-panel fatigue test specimen.

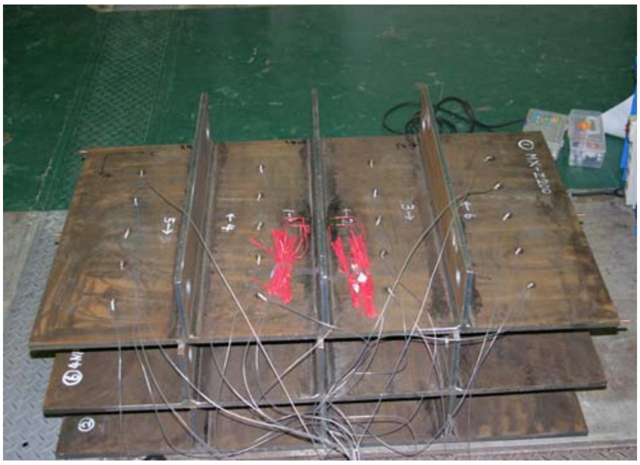


Fig.3 Positions of sensing pin for FSM.

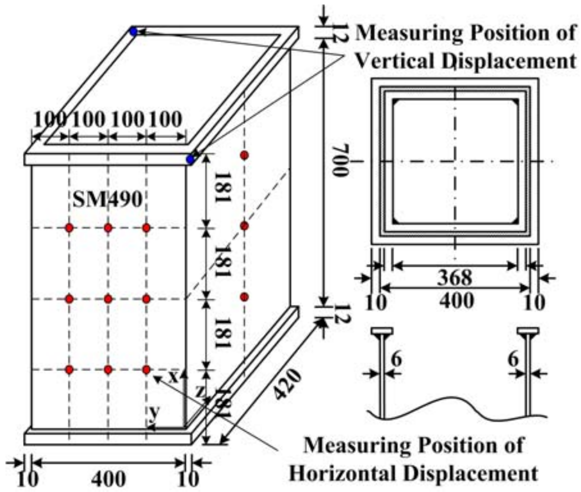


Fig.4 Dimensions of structure test specimen.

Fig.5 Experimental View of box structure.

3. Experimental Result and Discussion

3.1 Welding distortion

3.1.1 Plane-panel test specimen

Before the correction of the out-of-plane distortion for the 3-point bending fatigue test, the welding distortion is measured. **Table 5** shows the results of welding distortion of plane-panel test specimens. From these results, it is shown that the welding distortion of plane-panel test specimens, manufactured by the developed wire, is generally small than that, manufactured by the existing wire. But, the value difference between plane-panel test specimens manufacture by the two welding wires is not so large. This means that the control capacity of welding distortion is not just decided by the welding consumable.

3.1.2 Box structure

Figure 6 shows the results of welding distortion of box structure. From these results, it is shown that the welding distortion of box structures, manufactured by the developed wire, is slightly small than that, manufactured by the existing wire. And, it can be estimated that there are the same reasons for plane-panel test specimens.

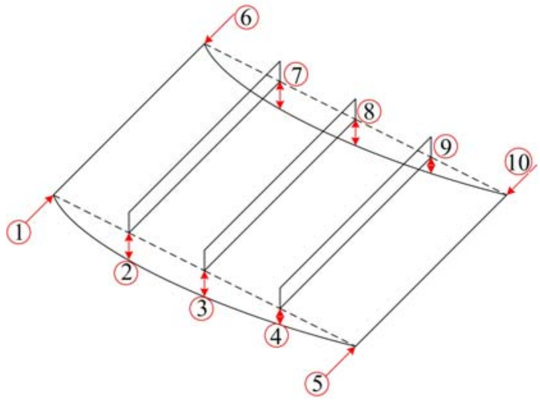
3.2 Fatigue tests of welded joints

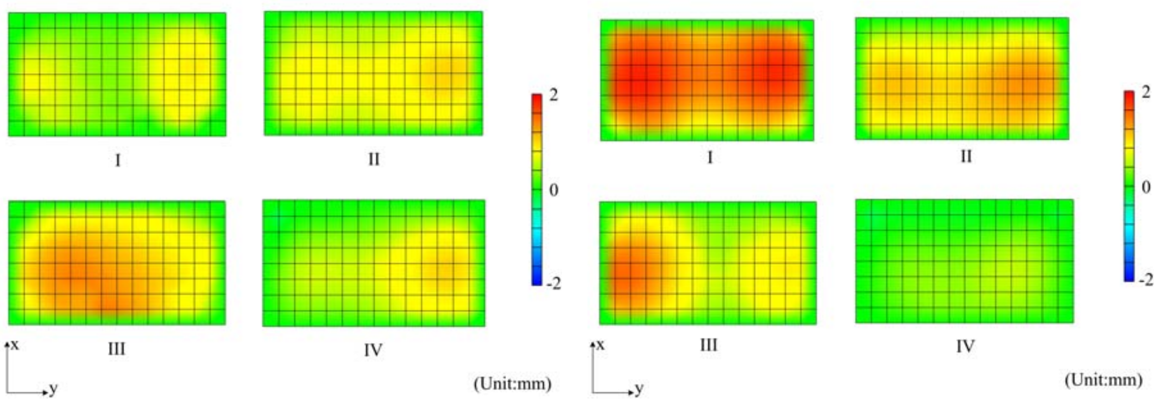
First of all, the fatigue test is carried out with non load-carrying type and load-carrying type fatigue test specimens using an existing and a newly developed wire. With these results, the fundamental fatigue characteristics for the small-sized test specimen are grasped. After that, the 3-point bending fatigue test was carried out with the plane-panel fatigue test specimen. The fatigue characteristics are investigated through the overall decision of those results.

3.2.1 Fatigue test of small-sized fatigue test specimen

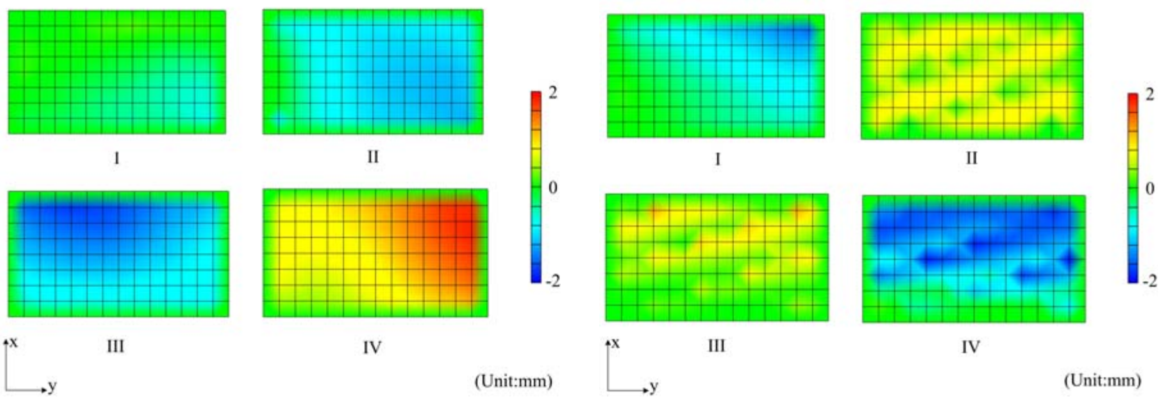
Figure 7 shows the results of fatigue test with small-sized fatigue test specimen.

Table 5 Results of welding distortion of plane-panel test specimen.

Measuring Position		Existing Wire			Developed Wire			Remarks
		I	II	III	I	II	III	
Deflection (mm)	①	0	0	0	0	0	0	
	②	15	15	15	13	12	13	
	③	19	18	18	17	14	15	
	④	15	14	14	12	12	12	
	⑤	0	0	0	0	0	0	
	⑥	0	0	0	0	0	0	
	⑦	17	14	15	14	12	13	
	⑧	20	19	16	18	15	16	
	⑨	14	14	14	13	12	12	
	⑩	0	0	0	0	0	0	



(a) Existing welding wire.

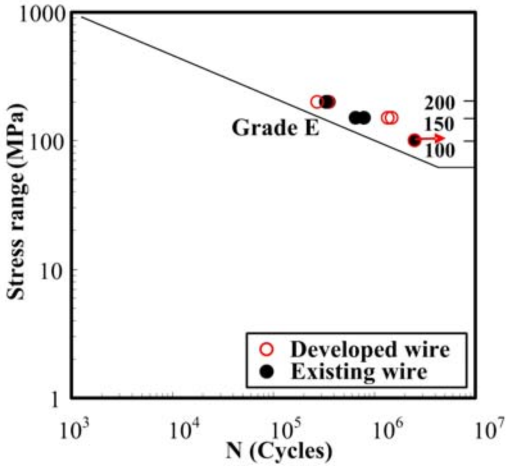


(b) Newly developed welding wire.

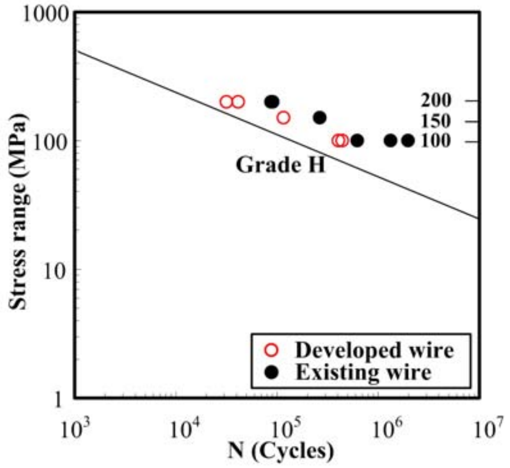
Fig.6 Results of welding distortion of box structure.

Figure 7(a) shows the results of fatigue test for the non load-carrying type fatigue test specimen using an existing and the newly developed wire. **Figure 7(b)** shows the results of fatigue test for the load-carrying type fatigue test specimen using an existing and developed wire. **Figure 8(a)** and **Figure 8(b)** shows the position of failure and the macrographs.

From these results, all the test specimens using an existing and a newly developed wire are broken at the weld toe in the case of non load-carrying type fatigue test specimens. The test specimen using an existing and developed wire have the same fatigue strength respectively. However, in the case of load-carrying type fatigue test specimen, the test specimen using an existing wire is



(a) Non load-carrying type fatigue test specimen.



(b) Load-carrying type fatigue test specimen.

Fig.7 Results of fatigue test with small-sized fatigue test

Existing wire(at weld toe) Newly developed wire(at weld toe)

(a) Non load-carrying type fatigue test specimen.

Existing wire(at weld toe and root) Newly developed wire(at root)

(b) Load-carrying type fatigue test specimen.

Fig.8 Position of failure and macrograph

broken from weld toe or root. All the test specimens using a developed wire are broken from the root.

Meanwhile, the fatigue strength of test specimen using a developed wire is a little lower than that of the test specimen using an existing wire.

The fatigue strength of every small-sized fatigue test specimen satisfied the stress category of Japan Standard of Stress Category (JSSC).

3.2.2 Fatigue test of plane-panel test specimen

Figure 9 shows the results of 3-point bending fatigue tests.

The 3-point bending fatigue test was carried out for three test specimens. The stress amplitude is decided by reference to the results of small-sized fatigue tests. However, any other fatigue crack is not detected. So, the 3-point bending fatigue test is progressed while raising the stress amplitude. But, the fatigue crack was not generated up to E-grade of stress category (JSSC) for each plane-panel fatigue test specimen using an existing and developed wire. So, the 3-point bending fatigue test is finished. At that time, the fatigue crack is checked using a FSM (Field Signature Method).

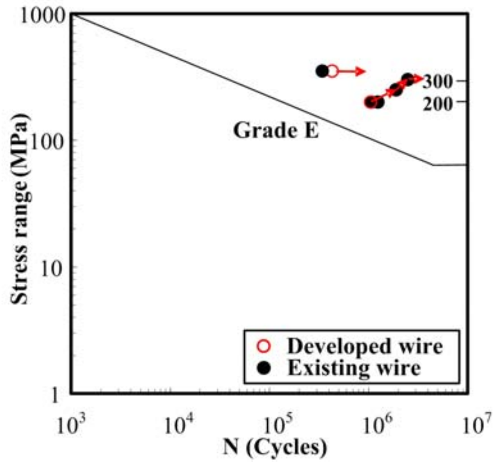


Fig.9 Results of 3-point bending fatigue test.

Figure 10 shows the FC value getting by FSM. The generation of a fatigue crack is estimated from an increase of FC value in stages. But, there is not any sign of increase in FC value. So, it is known that the fatigue crack has not been generated. The variation of FC value in figure11 (a) seems to increase, but, this is a phenomenon due to raising the stress amplitude.

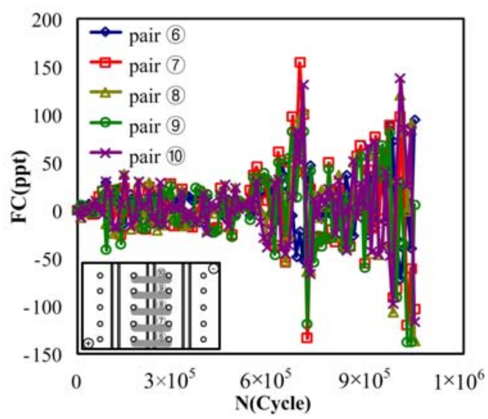
According to the results of fatigue tests with small-sized and plane-panel fatigue test specimens, the stress category is satisfied with the demanded stress category of the steel fatigue design guide. Fatigue strength also satisfied the demand.

3.3 Compressive test of box structure

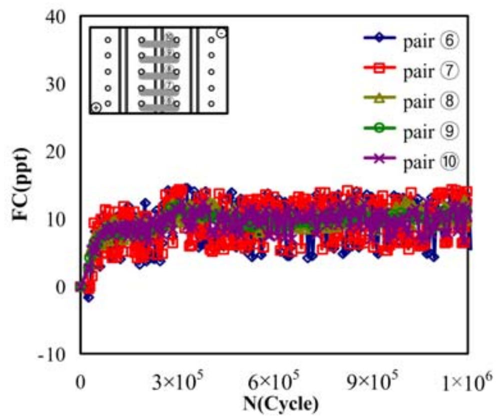
The compressive test of box structure using an existing and developed wire was carried out. The compressive test is for the confirmation of generation of cracks at the welded joint under the ultimate load.

Figure 11 (a) shows the load-vertical displacement curve.

The compressive strength of a box specimen using an existing and developed wire is more than the ultimate

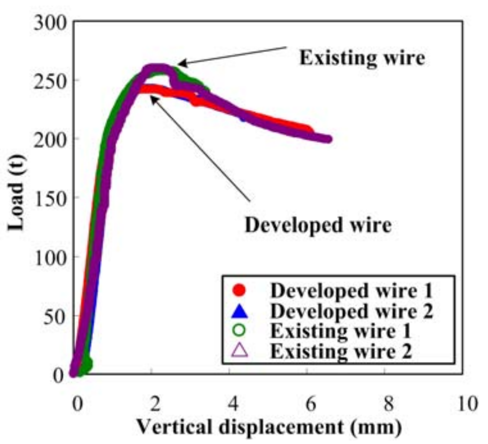


(a) Existing wire

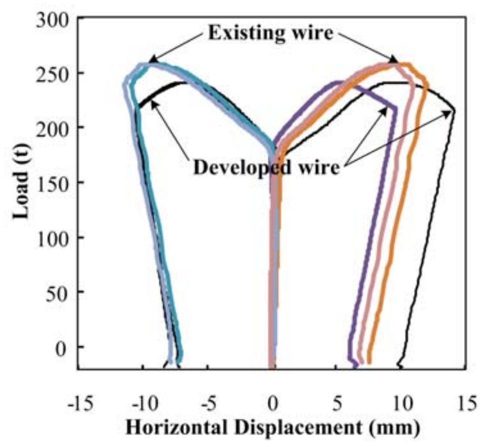


(b) Newly developed wire

Fig.10 Results of FC value.



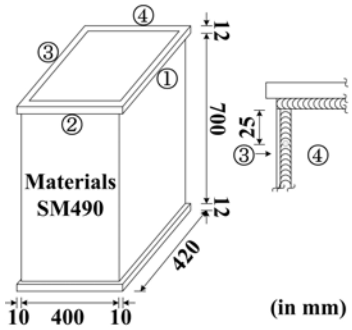
(a) Load-vertical displacement



(b) Load-horizontal displacement

Fig.11 Load-displacement curve.

Table 6 Results of penetrant test.

Measuring Position		Crack		Remarks
		I	II	
①→②	Inside	None	None	
	Outside	None	None	
②→③	Inside	None	None	
	Outside	None	None	
③→④	Inside	None	None	
	Outside	?	None	
④→①	Inside	None	None	
	Outside	None	None	

strength of material. And, the since out-of-plane displacement in the middle part(x=350, y=200(mm)) of box height direction is almost not generated, **Figure 11 (b)** shows the compressive load-horizontal displacement at the peak of sine curve. The behavior of out-of-plane displacement is vertically symmetry. The out-of-plane displacement is rapidly increased near the compressive load 150t. At that time, the buckling of the panel is beginning. After the compressive test, the penetrant test is carried out on those test specimens. **Table 6** shows the results of Penetrant test. Though the sign like crack is detected, the crack is not detected at welds of those test specimens.

4. Conclusion

In order to decrease the consumption of energy accompanying the correction of welding distortion, a welding wire was newly developed. Based on the mechanical characteristics of welded joints using an existing wire, the mechanical characteristics of welded joints using a developed welding wire were evaluated. The soundness of structures using the developed wire was evaluated based on the mechanical characteristics of welded joints according to each wire.

Despite the fact that the mechanical characteristics of the developed wire are a little inferior to existing wire, it does not present much of a problem for practical use from the overall point of view.

Reference

1) OKU Kentaro, ARITA Keisuke, and KIM You-Chul : Monitoring of Initiation and Propagation of Fatigue Crack by Field Signature Method, Steel Construction Engineering, 13-50(2006.06), pp.35-43(in Japanese).