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EXPERIMENTAL STUDY ON EFFECTS OF MECHANICAL PROPERTIES OF BEAM MATERIALS ON DEFORMATION CAPACITY OF BEAM/COLUMM CONNECTIONS

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ABSTRACT

The mechanical property of the beam flange influences the deformation capacity. When yield point, the yield ratio and strain hardening rate are low, deformation capacity of beam to column welded connection excels. 0℃ Charpy absorbed energy of heat affected zone which was the fracture starting point was 130J or more. The Charpy absorbed energy at 0℃ of the beam flange did not influence the deformation capacity. The specimen of the plastic region with a low yield ratio is larger than the specimen with a high yield ratio.

Keywords:

beam-to-column welded connection, mechanical property, fracture toughness, non-scallop method, deformation capacity

1.Introduction

HyogoKen-Nanbu Earthquake in 1995, brittle fracture to accompany beam-ends junction of an architectural iron frame the plastic deformation was confirmed. Absorbed energy (vEo) of 0℃ by the Charpy impact test of the steel material is thought by one of factors which influence brittle fracture at the edge of the beam[1]-[3]. In the SM material (B and C material) and SN materials (B and C material), the lower bound value of vEo is provided for. This research aims the examination of the mechanical property and vEo of the steel material used for the beam of the influence given to the deformation capacity of junction by using the specimen which models the beam-column welded connection.

2.Outline of experiment

2.1 specimen shape and experiment parameter

The specimen assumed the shop welding junction type. The size of the beam used six kinds of steel materials of B material of A material of rolling H shape steel RH-400×200×13×21, C material, H material, and welding assembly H shape steel BH-400×200×12×25, E materials, and F materials. It indicates the mill sheet value of a mechanical property and a chemical element in Table 1. It assumed the beam-ends detail to be a scallop industrial method (Are of the scallop bottom was 10mm) and a non scallop industrial methods. Figure 1 shows the specimen shape. Of each of the scallop specimen and the non scallop specimen which used six kinds of steel materials at 0℃ in examination temperature; The non scallop specimen of five steel kind did the load testing room temperature (17℃-20℃).

Table 2 shows the experiment parameter. The loading was based on amount c δ p of the bending deformation at all plasticity yield strength (cPp) of obtaining the beam material all sections as effective. Figure 2 shows the loading pattern.

Table1. Mechanical property and Chemical element

beam	upY.P. (N/mm^2)	lowY.P. (N/mm^2)	ε st (%)	T.S. (N/mm^2)	ε u (%)	Y.R. (%)	EL. (%)
A	409	391	1.29	555	15.2	74	28
B	332	332	0.55	528	16.1	63	31
C	386	364	1.27	548	15.6	71	29
E	330	322	0.80	514	16.1	64	33
F	318	311	0.45	511	15.0	62	29
H	400	374	1.44	536	16.4	75	31
A(web)	441	414	2.01	552	16.0	80	30
B(web)	394	372	1.20	535	15.5	74	29
C(web)	442	416	2.31	550	15.9	80	30
E(web)	397	375	1.31	558	16.0	71	28
F(web)	399	382	1.39	555	15.6	72	27
H(web)	449	408	2.29	542	16.4	83	32

upY.P:Yield point LowY.P:Yield point in the under ε st:Strain when strain st
T.S:Tensile strength ε u:T.S . Strain at time Y.R:Yield ratio E

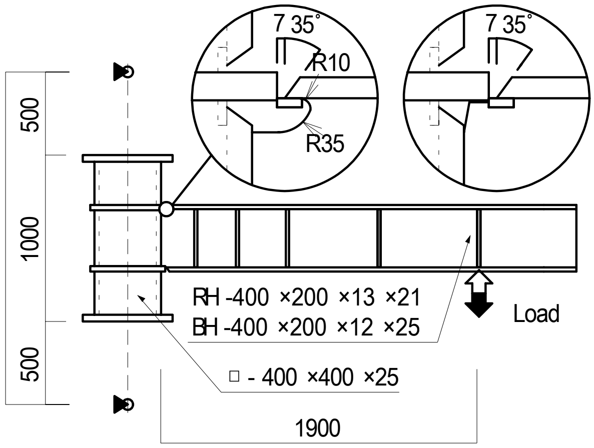

Fig.1. Specimen shape

Table 2 Experiment parameter

specimen	beam		detail	temp.
As0	A	RH	scallop	0°C
Cs0	C			
Hs0	H			
Bs0	B	RH	scallop	0°C
Es0	E			
Fs0	F			
An0	A	RH	non scallop	0°C
Cn0	C			
Hn0	H			
Bn0	B	RH	non scallop	0°C
En0	E			
Fn0	F			
Cn1	C	RH	non scallop	17°C ~ 20°C
Hn1	H			
Bn1	B	RH	non scallop	17°C ~ 20°C
En1	E			
Fn1	F			

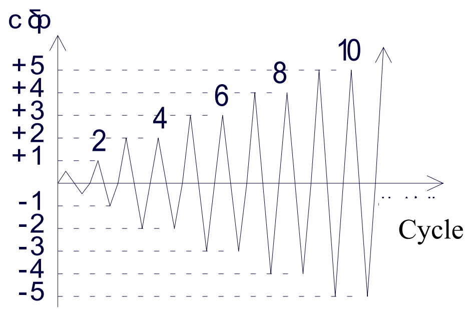

Fig.2 Loading plan

2.2 Material examination of steel material used for beam

It investigated the flange parent metal of each steel material and the material property in the weld with the butt weld splice. Table 3 shows the tension test result. H material and A material of yield point were high, and, next, C material, B material, E material, and F material were low values. The yield ratio became a high result in order of H material >A material >C material >E material >B material >F material. Table 4 shows the Charpy impact test result. The specimen name shows the kind and the position where it gathers the steel material. S shows the parent metal, f shows fillet, and h shows HAZ.

Table.3 Tension test result

beam	upY.P. (N/mm^2)	lowY.P. (N/mm^2)	ε st (%)	T.S. (N/mm^2)	ε u (%)	Y.R. (%)	EL. (%)
A	409	391	1.29	555	15.2	74	28
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upY.P:Yield point LowY.P:Yield point in the under ε st:Strain when strain stiffens
T.S:Tensile strength ε u:T.S . Strain at time Y.R:Yield ratio EL.:Elongation

Table. 4 Charpy impact test result

	specimen	vEo (J)	vBo (%)	Tre (℃)	Trs (℃)
parents (s)	A s	19	88	22	24
	B s	34	88	33	34
	C s	286	1	-51	-48
	E s	240	15	-39	-27
	F s	283	6	-28	-23
	H s	55	78	23	16
HAZ (h)	A h	199	7	-31	-28
	B h	160	47	-7	-1
	C h	250	2	-33	-33
	E h	200	33	-23	-13
	F h	260	10	-30	-27
	H h	130	47	3	-2
fillet (f)	A f	24	85	-	-
	C f	282	0	-	-
	H f	68	77	-	-
Weld Metal	RH Depo	80	60	3	8
	BH Depo	28	88	51	42

3. Experiment result

3.1 destruction properties

All specimens except Cn0 destroyed the brittleness from the edge of the width of the flange in the beam flange welding toe of weld part. Cn0 destroys the brittleness from the welding first layer neighborhood. The destruction is the following two types.

① In the direction of the width of the flange when the position becomes a starting point within 10mm. There are a lot of cases of 0℃.

② When the position at 10mm or more becomes a starting point in the direction of the width of the flange. There are a lot of cases of room temperature.

The P- δ curve of Fn1 and Hn1 decreases gradually when the load when maximum displacing increases the cycle, and the load has decreased obviously at the cycle to breaking.

3.2 skeleton curve and deformation capacity's indices

It requested from the P- δ curve, and it shows the method of calculating the skeleton curve and the accumulation plastic deformation irreversible deformation in Figure 3. The skeleton curve accumulated and obtained the P- δ curve for the load to have exceeded the maximum value of the pre-loop in the P- δ curve. Table 5 shows the experiment result list. Accumulation value (Σ W) of the energy requested from energy (Ws) requested from the skeleton curve shown in Figure 5 when it compares deformation capacities of junction and each loop of the P- δ curve is thought. The actual experiment requested by expression 1 and 2, and examines the result by η s and η w. It examines η sF and η wF obtained by expression 3 and 4.

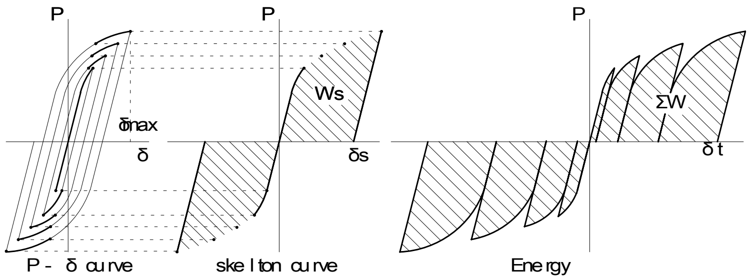

Fig.3 Skeleton curve

$$\eta_S = W_S / {}_C P_P \times {}_C \delta_P \quad \cdot \cdot (1)$$

$$\eta_W = \sum W / {}_C P_P \times {}_C \delta_P \quad \cdot \cdot (2)$$

$$\eta_S \mathrm{F} = W_S / {}_C P_P \mathrm{F} \times {}_C \delta_P \mathrm{F} \quad \cdot \cdot (3)$$

$$\eta_W \mathrm{F} = \sum W / {}_C P_P \mathrm{F} \times {}_C \delta_P \mathrm{F} \quad \cdot \cdot (4)$$

$${}_C P_P = Z_P \times Y.P./L, {}_C P_P \mathrm{F} = Z_P \times 325/L$$

Table.5 Experiment result

	Pmax (kN)	δ max (mm)	δ s (mm)	Ws	Σ W	δ t (mm)	Material examination result					※F= (3.3)					Fracture Type
							cPp	c δ p	η s	η w	α	cPpF	c δ pF	η sF	η wF	α F	
As0	-546	-46.3	-42.0	20075	81999	-194.9	439	16.13	2.8	11.6	1.2			4.7	19.1	1.6	①
Cs0	538	59.8	54.9	26038	120926	289.7	420	15.43	4.0	18.6	1.3	342	12.56	6.1	28.2	1.6	①
Hs0	-567	-54.8	-59.3	29247	133808	-304.1	434	15.92	4.2	19.4	1.3			6.8	31.2	1.7	①
Bs0	587	60.9	59.7	31025	128344	278.8	404	13.65	5.6	23.3	1.5			6.3	26.0	1.5	①
Es0	610	67.8	66.0	35827	191792	408.0	402	13.60	6.5	35.0	1.5	382	12.91	7.3	38.9	1.6	①
Fs0	-608	-59.2	-57.2	29957	146033	-322.3	391	13.22	5.8	28.3	1.6			6.1	29.6	1.6	①
An0	-594	-60.8	-67.5	35434	160711	-349.4	439	16.13	5.0	22.7	1.4			8.2	37.4	1.7	②
Cn0	-600	-69.0	-65.9	34208	182781	-405.3	420	15.43	5.3	28.2	1.4	342	12.56	8.0	42.6	1.8	①
Hn0	-615	-67.7	-70.0	37730	196350	-417.8	434	15.92	5.5	28.5	1.4			8.8	45.7	1.8	①
Bn0	623	72.3	90.0	50271	272380	544.8	404	13.65	9.1	49.4	1.5			10.2	55.2	1.6	①
En0	642	81.2	85.7	49216	265414	526.0	402	13.60	9.0	48.5	1.6	382	12.91	10.0	53.8	1.7	①
Fn0	-674	-70.5	-72.0	42081	246618	-487.4	391	13.22	8.1	47.7	1.7			8.5	50.0	1.8	①
Cn1	-585	-71.4	-66.6	34035	220174	-497.4	420	15.43	5.2	34.0	1.4	342	12.56	7.9	51.3	1.7	②
Hn1	574	94.1	99.6	52061	352284	767.6	434	15.92	7.5	51.1	1.3			12.1	82.0	1.7	②
Bn1	-646	-71.5	-81.3	45343	255987	-426.5	404	13.65	8.2	46.4	1.6			9.2	51.9	1.7	②
En1	631	94.7	101.1	57762	413220	814.8	402	13.60	10.5	75.5	1.6	382	12.91	11.7	83.8	1.7	②
Fn1	612	83.1	71.8	39490	330447	675.5	391	13.22	7.6	63.9	1.6			8.0	67.0	1.6	②

Pmax :maximum load δ max :maximum displacement δ s :Skeleton displacement (plasticity) Ws :Skeleton absorbed energy
ΣW :Accumulation absorbed energy δt :accumulation plastic deformation
cPp :All plasticity yield strength cδ p :bending deformation at all plasticity yield strength η s :Ws/ cPp･cδ p η w :Σ W/ cPp･cδ p α :Pmax/ cPp

4. Consideration

4.1 strain properties

It obtained load-skeleton strain (ε s) curve by the method of calculating the skeleton curve shown from load-strain (ε) curve in Figure 3. Figure 4 shows one example of the ε s- δ s curve obtained from P- ε s and P- δ s (70mm of Cs0). δ s compared ε s at 45mm(4c δ pF) with each specimen in the ε s- δ s curve.

Figure 5 shows the position where it affixes the strain gage used for the comparison.

Figure 6 shows the η sF- ε s relation between the scallop specimen and the non scallop specimen at 0℃. There is a tendency to which η sF becomes small when ε s is large from Figure 8(a) and (b). The skeleton strain becomes small a non scallop specimen compared with the scallop specimen. Moreover, the specimen with a low yield ratio of the beam material shows the tendency that ε s is small.

It can be said that the deformation capacity will grow by strain at the edge of the beam small. Moreover, it can be said that the specimen with a low yield ratio and the non scallop specimen extend the plastic region compared with the specimen with a high yield ratio and the scallop specimen, and strain at the edge of the beam has the tendency which becomes small.

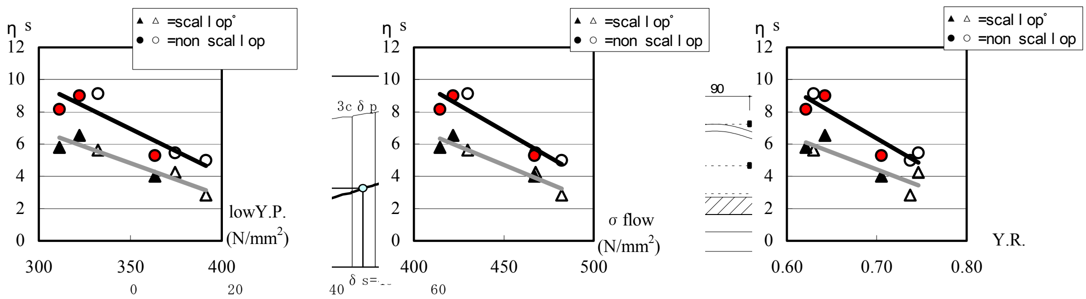

Fig.7 η s－lowY.P. Fig.8 η s－ σ flow Fig.9 η s－Y.R.

Fig.4 ε s－ δ sCurve（Cs0, Fig.5 Gauge affixation position

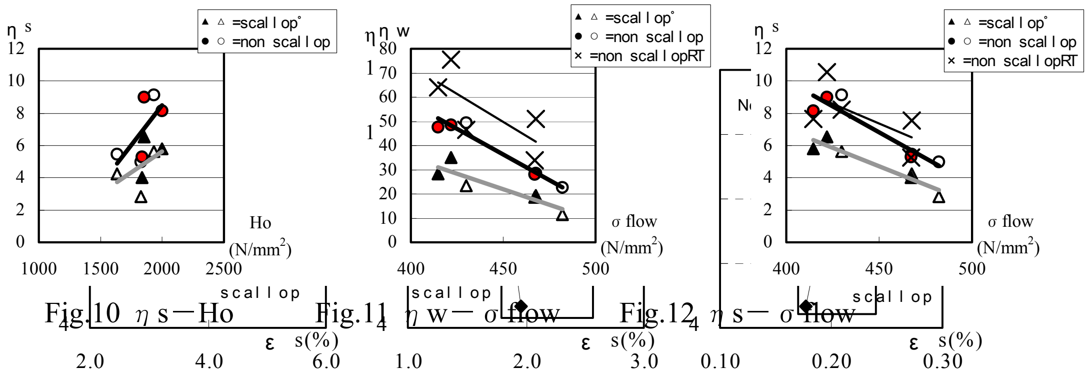

Fig.10 η s－Ho Fig.11 η w－ σ flow Fig.12 η s－ σ flow

(a) 30mm²Ave (b) 70mm (c) 550mm

Fig.6 η sF－ ε s（at 0℃）

4.2 Influence of mechanical property of beam material

It shows the relation between η s and the material property by which it makes Ws obtained from the skeleton curve dimensionless according to yield strength of the material examination result below. When it assumes the material property to be a parameter, yield point, tensile strength, the yield ratio, and the strain hardening rate etc. of the steel material are thought.

σ flow is a value divided by two adding yield point and tensile strength. Figure 7-Figure 10 shows η s and each relation. LowY.P . There is a correlation in σ flow, Y.R, and η s.

Moreover, η s has the growing tendency as the strain effect rate of Figure 10 grows similarly. When it uses the same steel material for the beam, deformation capacities grow more than the scallop specimens as for the non scallop specimen. The influence of the mechanical property is larger in η s. It considers it with η w and η s which makes accumulation plasticity absorbed energy (Σ W) of the specimen at room temperature dimensionless. Figure 11 and Figure 12 show the η w- σ flow relation and the η s- σ flow relation. There is a tendency which grows as σ flow becomes small η w as well as η s. In the experiment on room temperature, a tendency different from the η s- σ flow relation is seen about the non scallop specimen. The difference between the specimen of room temperature and the specimen of 0℃ grows if it evaluates it with η w.

5. Summary

a) Mechanical properties have significant influence on deformation capacity. Deformation capacity of beam to column welded connections is increased withthe decrease of the yield point, the yield ratio and the strain hardening rate of the materials.

b) The Charpy impact toughness has little influence on the deformation capacity provided that the absorbed energy of heat affected zone at 0℃, from which the fracture initiates, is 130J or more.

c) The plastically deformed zone of the components is larger in the materials of low yield ratio, and the skeleton strain at the end of beam is generally small in the low yield ratio materials.

d) The detail of connection, whether it has a scallop or not, has relatively smaller influence on the deformation capacity than the mechanical properties of materials used.

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