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TS520 N/mm² Class SHH Shapes Manufactured by Thermo-Mechanical Control Process (TMCP) for Building Frames "HBL™-H355" †

1. Introduction

Following the Great East Japan Earthquake on March 11, 2011, further improvement in the earthquake resistance of buildings has been demanded. Accompanying the recent trends toward high-rise and long-span construction in buildings, examples of application of large section, high strength welded H-shapes have also increased. In response, JFE Steel developed Japan's first 520 N/mm² class TMCP H-shape "HBL™-H355" for building construction (with maximum strength) as a fixed outer dimension H-shape product (**Photo 1**) (TMCP: Thermo-Mechanical Control Process). This report presents an outline of HBL™-H355.

Photo1 HBL™-H355

2. Properties of Steel

HBL™-H355 is a rolled H-shape steel which was certified by Japan's Minister of Land, Infrastructure, Transport and Tourism in April 2011. **Table 1** shows the standard and performance for chemical composition and mechanical properties. While HBL™-H355 products have the same carbon equivalent as SN490 (JIS G 3136, JIS: Japanese Industrial Standards), high tensile strength of TS520 N/mm² or more and low yield ratio are realized by using appropriate hot rolling and advanced

Table 1 Standard and performance

Size (mm)	Chemical composition (%)							Tensile test (Test piece: JIS No. 1A)				Charpy impact test
	C	Si	Mn	P	S	C_{eq}	P_{CM}	YP or YS (N/mm²)	TS (N/mm²)	YR(%)	EL (%)	$_{V}E_0$ (J)
H1 000×400×16×32	0.17	0.31	1.27	0.020	0.003	0.40	0.25	407	548	74.3	31	232
H900×400×19×40	0.17	0.33	1.28	0.020	0.003	0.40	0.25	407	560	72.7	30	248
Spec.	≦0.20	≦0.55	≦1.65	≦0.030	≦0.015	≦0.44	≦0.29	355−475	520−640	≦80	19≦	27≦

C_{eq}=C+Mn/6+Si/24+Ni/40+Cr/5+Mo/4+V/14
P_{CM}=C+Mn/20+Si/30+Cu/20+Ni/60+Cr/20+Mo/15+V/10+5B

YP: Yield point YS: Yield strength TS: Tensile strength YR: Yield ratio
EL: Elongation $_{V}E_0$: Charpy absorbed energy at 0°C

Table 2 y-Groove weld cracking test

Thickness (mm)	Welding process	Welding material	Pre-heat temperature (°C)	Cracking (%)
40	GMAW (CO_2)	YGW18	5	0
			25	0

GMAW: Gas metal arc welding YGW18: JIS Z 3312

Table 3 Maximum hardness test (Vikers hardness)

Thickness (mm)	Welding process	Bead length					
		Arc strike	10 mm	20 mm	40 mm	50 mm	125 mm
40	SMAW	412	368	347	315	282	287
	GMAW (CO_2)	401	371	331	301	294	280

SMAW: Shielded metal arc welding GMAW: Gas metal arc welding

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accelerated cooling technologies, taking advantage of JFE Steel’s shape steel cooling device “*Super*-OLAC™ S”. **Table 2** shows the results of a y-groove weld cracking test, and **Table 3** shows the results of a maximum hardness test. Although the tests were performed by gas metal arc welding (GMAW; CO_2 welding) at pre-heat temperatures of 5°C and 25°C, no cracking occurred at either temperature. In the maximum hardness test, the maximum hardness with both GMAW and shielded metal arc welding (SMAW) was less than Vickers hardness of 350, which is the criterion for prevention of weld cracking with the minimum bead length of 40 mm in assembly welding specified in JASS6 [1]. From these results, HBL™-H355 has excellent weldability, similar to that of SN490. A multi-pass welded joint test [2] was also performed, and satisfactory joint strength and toughness were confirmed.

3. Bending Performance

3.1 Outline of Experiment

A 3-point bending test was performed to confirm bending performance. The dimensions of the test piece are shown in **Fig. 1**. The test parameter was determined by the upper and lower limits of the flange width-thickness ratio in the current size range.

3.2 Results of Experiment

Figure 2 shows the relationship between plastic deformation magnification, R (plasticity rate (μ) −1), and the normalized flange width-thickness ratio. Plastic deformation magnification was 9.5 with No. 1 and 14 with No. 2, greatly exceeding the plastic deformation magnification requirement [3]. Examples of data for other steel grades [4] are also shown in the figure. It can be understood that the developed steel possesses approximately the same deformation performance as the other steel grades.

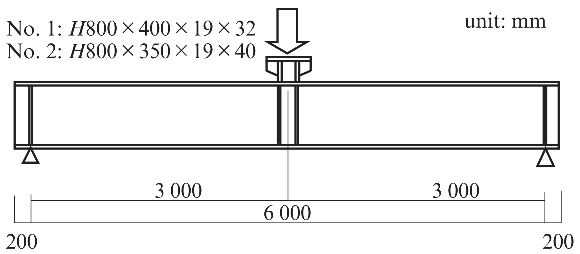

Fig. 1 Test detail

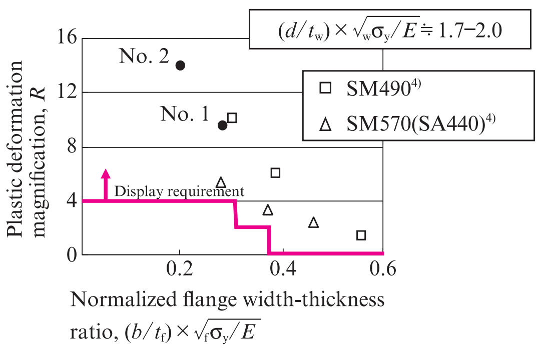

Fig. 2 Plastic deformation magnification (R)-Normalized flange width-thickness ratio relationship

4. Product Features and Available Size Range

The developed product has a design strength (F value) of 355 N/mm² and makes it possible to reduce the weight of steel by a maximum of 9% in comparison with SN490, thereby enabling economical design and construction. Because the flange thickness can be reduced by approximately 1 size in comparison with SN490 as a result of this higher strength, HBL™-H355 is effective for reducing the amount of welding in beam-to-column joints and the thickness of diaphragm plates installed in columns, etc.

The available size range of the product is shown in **Fig. 3**. Product sizes were selected from the existing series in JFE Steel’s lineup of fixed outer dimension H-shapes “Super HISLEND™ H,” [5] centering on large sections, and 14 series comprising 52 sizes with heights from 700 mm to 1 000 mm and widths from 300 mm to 400 mm were commercialized.

5. Conclusion

An outline of 520 N/mm² class TMCP H-shape

unit: mm

Depth \ Width		300		350			400		
		32	36	32	36	40	32	36	40
700	9								
	12								
	14			●					
	16			●	●				
750	12								
	14			●					
	16			●	●				
800	14								
	16			●	●		●	●	
	19			●	●	●	●	●	●
850	14								
	16			●			●		
	19			●	●	●	●	●	●
900	16			●			●		
	19			●	●	●	●	●	●
950	16			●			●		
	19	●	●	●	●	●	●	●	●
1 000	16			●			●		
	19	●	●	●	●	●	●	●	●

Fig. 3 HBL™-H355 Section table

“HBL™-H355” for building construction was presented. This product provides a combination of high strength and excellent weldability, and because it has a high deformation capacity, its seismic performance is also excellent, enabling construction of safe, secure buildings. In the future, JFE Steel will continue to develop new products matched to customer needs.

References

1) Architectural Institute of Japan. Japanese Architectural Standard Specification JASS6 Steel Work. 2007, p. 19. (Japanese)
2) Kimura, Tatsumi et al. JFE Technical Report. 2011, no. 16, p. 52–57.
3) Architectural Institute of Japan. Recommendation for Limit State Design of Steel Structures. 1998-10. (Japanese)
4) Kato, Ben; Nakao, Masami. Strength and deformation capacity of H-shaped steel members governed by local buckling. Transactions of AIJ. Journal of Structural and Construction Engineering. 1994-04, no. 458, p. 127–136. (Japanese)
5) For example, “JFE-no H-Katako,” JFE Catalog. cat. no. D1J-101-06. (Japanese)

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