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AN EXPERIMENTAL STUDY ON MECHANICAL PROPERTIES OF SBHS700 AND APPLICATION OF SBHS700 TO STIFFENED PLATES

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ABSTRACT

Higher yield strength steel plates for bridges, SBHS, has been standardized by Japanese Industrial Standard (JIS). However, there is not enough information on the mechanical properties of SBHS700 compared with SM490 and SM570. In this study, tensile tests of SBHS700 were conducted to earn the information on mechanical properties and stress-strain relationship. Moreover, axial compressive tests were conducted with the stiffened box section test specimens whose stiffeners are made of SBHS700. According to the axial compressive tests, the ultimate strength and the ductility of hybrid stiffened plates by applying SBHS700 were investigated.

Keywords： SBHS700, mechanical properties, hybrid structures, ultimate strength, ductility

1. INTRODUCTION

"Higher yield strength steel plates for bridges" has been standardized in Japanese industrial Standard (JIS) (JIS G 3140 2008). The major feature of higher yield strength steel plates for bridges, SBHS, is high yield strength and high weldability. Among SBHS, SBHS700 has the highest yield strength and the highest tensile strength. Therefore, there is possibility of reduction in construction cost of steel bridges by applying SBHS700. However, information on stress-strain relationship and the mechanical properties like the yield stress, the tensile strength and the elongation of SBHS700 is not sufficient compared with the other rolled steel for welded structure like SM490 and SM570 (Murakoshi et al. 2008).

In this study, tensile tests of SBHS700 were conducted in order to earn the information on its mechanical properties and stress-strain relationship. Based on the test results, the feature of the mechanical properties and stress-strain relationships of SBHS700 was examined.

By the way, the ultimate strength of steel structures made of SBHS700 was examined in some previous studies and the target of them was steel girders involving the hybrid steel girders. This study focuses on the hybrid stiffened plates as the steel structures made of SBHS700.

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2. TENSILE TESTS

Tensile tests were conducted in order to obtain the information on mechanical properties and stress-strain relationship of SBHS700.

2.1 TEST SPECIMENS

Table 1 shows the type of test specimens and the number of test specimens. The tensile tests were conducted with the test specimens standardized by JIS. The test specimens were cut along rolling direction (L-specimen) and perpendicularly to rolling direction (R-specimen). The plate thickness is 9mm and 12mm. The total number of test specimens is 20.

Table 1: Number of test specimens

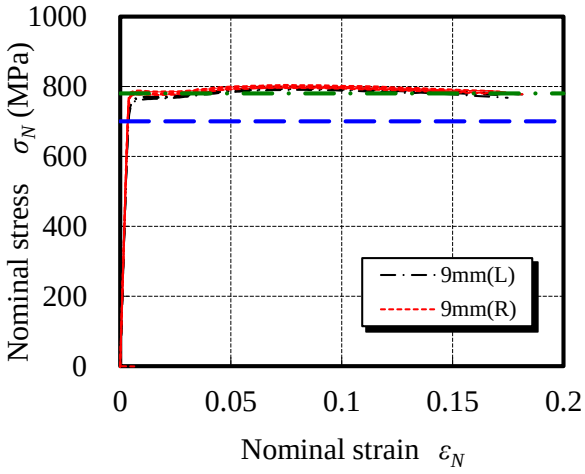
Steel type	Plate thickness	Cut direction	Number
SBHS700	9mm	Rolling (L-specimen)	5
		Perpendicularly (R-specimen)	5
	12mm	Rolling (L-specimen)	5
		Perpendicularly (R-specimen)	5

Table 2: Mechanical properties in JIS

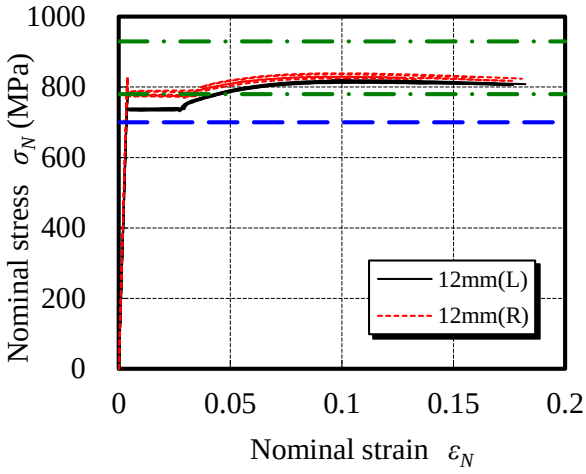
	Yield stress (MPa)	Tensile strength (MPa)	Elongation		
			Plate thickness (mm)	Specimens	Elongation (%)
SBHS700	700≦	780~930	6≦t≦16	JIS-5	16≦

Table 3: Results of tensile tests

Steel type	Plate thickness	Cut direction	Yield stress (MPa)	Tensile strength (MPa)	Yield ratio (%)	Elongation (%)
SBHS700	9mm	Rolling	770	796	97	25
		Perpendicularly	785	802	98	24
	12mm	Rolling	772	818	94	30
		Perpendicularly	826	835	99	28



(a) t = 9mm



(b) t = 12mm

Figure 1: σ_N - ε_N relationship

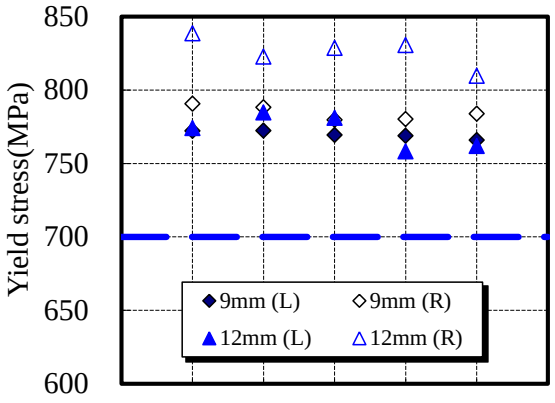


Figure 2: Yield stress

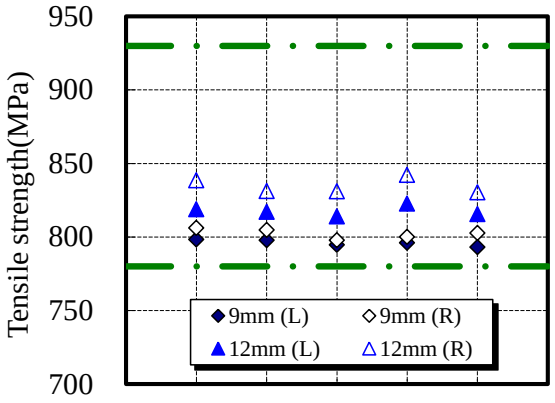


Figure 3: Tensile strength

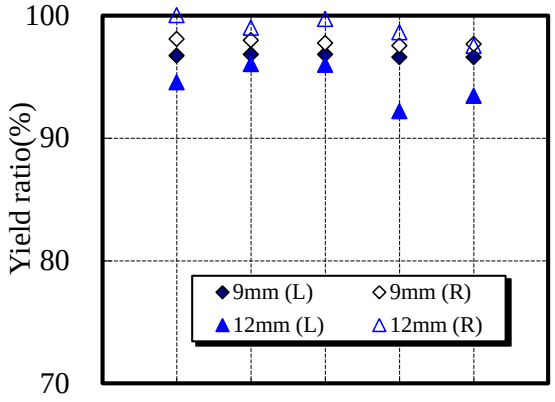


Figure 4: Yield ratio

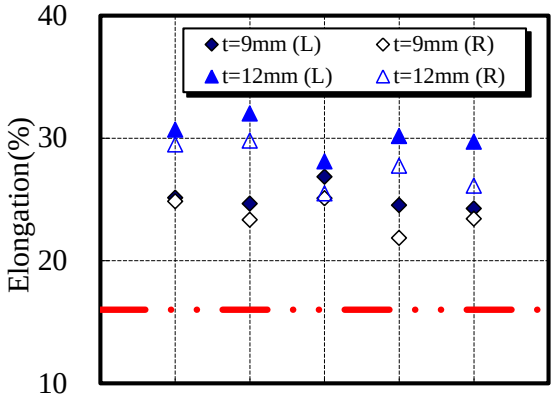


Figure 5: Elongation

2.2 TENSILE TEST RESULTS

Table 2 shows mechanical properties specified in JIS. Table 3 shows the average values of test results. Figure 1 shows the nominal stress - nominal strain (σ_N - ε_N) relationship obtained from the tensile tests. Figures 2, 3, 4 and 5 show the fluctuation of yield stress σ_y, tensile strength σ_B, yield ratio YR (σ_y/σ_B) and elongation, respectively. In these figures, the blue dotted lines (- - -) indicate the minimum yield stress specified in JIS and the green piece of dashed lines (- · -) show the range of tensile strength specified in JIS. In Figure 5, the red two-dot chain lines (- ·· -) show the minimum elongation specified in JIS. Table 3 shows the average values of test results.

The outline of the test results of SBHS700 is as follows.

- The yield stress of R-specimens of 12 mm is larger than that of L-specimens of 12mm. But the tensile strength of R-specimens of 12mm is almost the same as that of L-specimens of 12mm.
- The yield stress and the tensile strength of R-specimens of 9mm are almost the same as those of L-specimens of 9mm.
- The yield ratio of SBHS700 in this study exists between 92% and 100%. Especially, the mean value of the yield ratio of test results of R-specimen of 12mm is 99%.

3. AXIAL COMPRESSIVE TESTS

The axial compressive tests were carried out in order to earn the information on the ultimate strength and ductility of hybrid stiffened plates made of SBHS700.

3.1 TEST SPECIMENS AND TEST CONDITION

In this study, two test specimens were employed. Figure 6 shows the configuration of test specimens. The feature of two specimens is shown below.

- R_SS: A test specimen composed of homogeneous stiffened plates. Flange, webs and stiffeners are made of SS400.
- R_BHS: A test specimen composed of hybrid stiffened plates. Flanges and webs are made of SS400. Stiffeners are made of SBHS700.

Figure 8 shows stress-strain relationship of SS400 and SBHS700. As shown in Figure 8, yield stress and tensile strength of SBHS700 is much higher than those of SS400.

Table 4 shows major buckling parameters of test specimens and yield stress of steel plates. In Table 4, R_F is a width-thickness ratio parameter for overall buckling of the entire stiffened panels, R_R is a width-thickness ratio parameter for buckling of subpanels between stiffeners and R_S is a width-thickness ratio parameter for buckling of stiffeners. The following are definition of the parameters (Japan Road Association 2012).

$$R_F = \frac{B}{t}\sqrt{\frac{\sigma_y}{E}\frac{12(1-\mu^2)}{k_F\pi^2}} \quad (1)$$

$$R_R = \frac{B}{nt}\sqrt{\frac{\sigma_y}{E}\frac{12(1-\mu^2)}{k_R\pi^2}} \quad (2)$$

$$R_S = \frac{h_S}{t_S}\sqrt{\frac{\sigma_y}{E}\frac{12(1-\mu^2)}{k_S\pi^2}} \quad (3)$$

where, B=width of web panels or and flange panels; t=thickness of web or flange panels; E=Young's modulus; μ=Poisson's ratio; h_S=height of stiffener; t_S=thickness of stiffeners; n=number of subpanels, k_F, k_R(=4.0) and k_S(=0.43)= buckling coefficient

In the experiments, the compressive axial force was applied to each test specimen by using a test machine shown in Figure 7.

3.2 TEST RESULTS

Figure 9 indicates compressive axial force 'N' - axial displacement 'δ' relationship (N-δ relationship) of each test specimen. The symbols '◇' in Figure 9 show the points where maximum axial force 'N_{max}' was observed. As shown in Figure 9, it is found that axial displacement at N_{max} of the test specimen 'R_BHS' is almost 1.7 times larger than that of the test specimen 'R_SS' whereas N_{max} of the test specimen 'R_BHS' is almost the same as that of the test specimen 'R_SS'. By the way, the seismic performance that ductility is improved with containing increase in ultimate strength is sometimes required. Therefore, the test results in Figure 9 indicate the possibility that this seismic performance may be realized by adapting the stiffened hybrid structures whose stiffeners are made of SBHS 700.

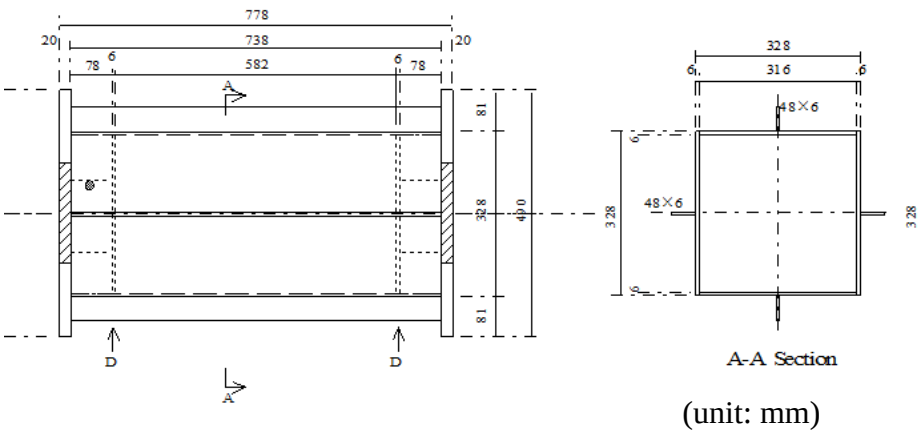


Figure 6: Outline of test specimens



Figure 7: Test set-up

Table 4: Steel type, yield stress and width-thickness ratio parameters

Specimens	Web, Frange		Stiffener		R_F	R_R	R_S
	Steel type	σ_y(MPa)	Steel type	σ_y(MPa)			
R_SS	SS400	235	SS400	235	0.42	0.48	0.44
R_BHS	SS400	235	SBHS700	750	0.42	0.47	0.78

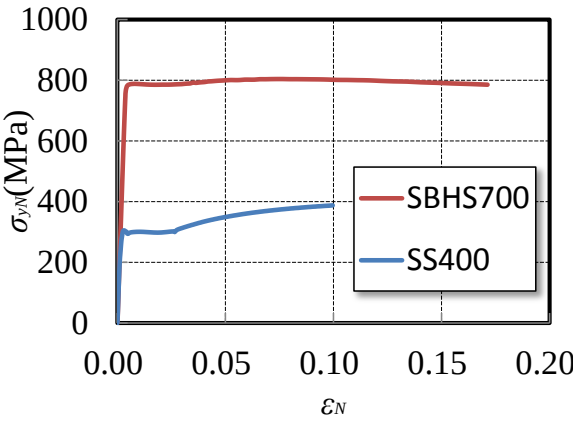


Figure 8: Stress-strain curves

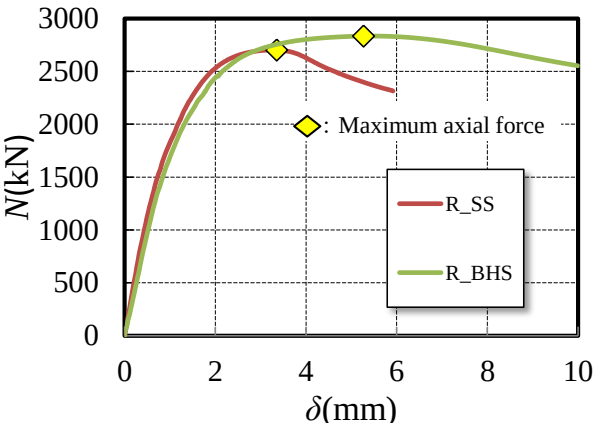


Figure 9: N-δ relationship

4 CONCLUSIONS

In this study, the tensile tests of SBHS700 were conducted. Based on results of tensile tests, the information on mechanical properties and stress-strain relationship of SBHS700 is obtained. Furthermore, axial compressive tests were conducted with a test specimen composed of homogeneous stiffed plates and that of the hybrid stiffed plates. The test results indicate the possibility that hybrid stiffened structures whose stiffeners are made of SBHS700 may realize the performance that ductility can be increased with containing increase in ultimate strength.

5 ACKNOWLEDGMENTS

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