CHARPY ABSORBED ENERGY OF COLD PRESS-BENT STEEL PLATES MADE OF SBHS400

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1. INTRODUCTION

The collapse of two bridge piers with rectangular cross-sections in the 1995 Kobe earthquake was caused by the rupture of the welded joints at the corner parts due to unexpected loading conditions. Facing such challenges, cold press-bent steel structures can be applied as a possible solution. However, strain aging of conventional steel materials caused by cold-forming may lead to a decrease in toughness and elongation, as well as an increase in hardness and strength. SBHS (Steels for Bridge High Performance Structure) was introduced in 2006 for its high yield strength, toughness, and workability. The high toughness of SBHS400 indicates the possibility to be a fitting steel material for cold press-bent structures. Therefore, this experimental study aims at evaluating the adverse effects of strain aging on the test pieces made of SBHS400.

2. EXPERIMENTAL METHODS

Vickerôs hardness test and Charpy absorbed energy test were conducted in this study, and the dimension of the test pieces is shown in Fig. 1. In the previous studies[1), 2)], the induced pre-strain through the tensile tests was considered to be uniformly distributed. However, the test pieces used in this study were cold-pressed into corner shapes, whose actual strain has linear distribution along the radial direction as shown in Fig. 1. Compressive strain is induced near the inner edge while tensile strain can be found near the outer edge correspondingly. Taking consideration of such strain distribution, the test pieces for Vickerôs hardness test and Charpy impact tests were taken at the location of the maximum curvature of the corner part. Vickerôs hardness test was conducted with 1 mm point interval along the radial direction at d=45° as shown in Fig. 2(a). Charpy impact tests were conducted at the same location with three test specimens with different orientations, as shown in Fig. 2(b). The tests were conducted after nearly one month, six months and one year of exposure. Flat plates without being cold press-bent are considered to be free of the strain aging effect. The number of test pieces for the Charpy impact tests are shown in Table 1.

Table 1 Number of the test pieces

	Flat plates		39 days		182 days		365 days	
(°C)	0	-60	0	-60	0	-60	0	-60
Outside	3	3	3	3	3	3	3	3
Center	3	3	3	3	3	3	3	3
Inside	3	3	3	3	3	3	3	3
Total	18		18		18		18	

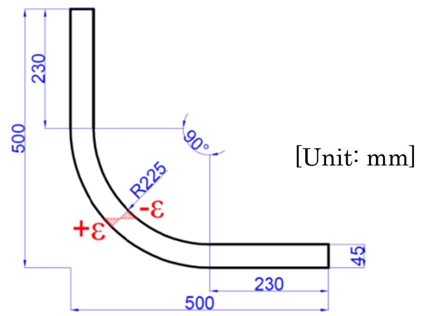
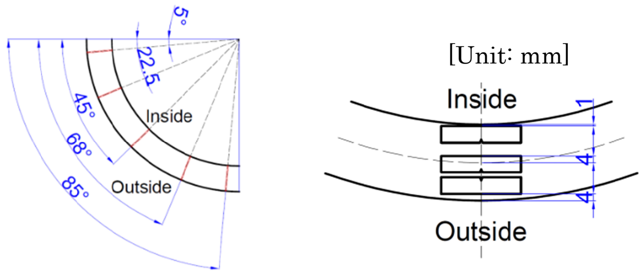


Fig. 1 Cold press-bent steel plates



(a) Vickerôs hardness test (b) Charpy impact test

Fig. 2 Locations of the test pieces

Keywords : Cold press-bent, SBHS400, Charpy absorbed energy, Vicker's hardness test, strain aging
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3. EXPERIMENTAL RESULTS

The results of the Vickerôs hardness test measured at the maximum curvature after 365 days as well as on a flat plate are shown in the same figure as the averaged Charpy absorbed energy measured after 365 days under the test temperature of 0 ℃ and -60 ℃ (Fig. 3). Lower hardness was observed near the center where the distance from outer surface is roughly 22.5 mm, and the difference was more significant for the corner part than the flat plate. Comparing with the outer and inner edges, absorbed energy at the center was lower even after the effect of strain aging. As Fig. 4 shows, little effect of strain aging on the absorbed energy was found under 0 ℃, while largely scattered data under -60 ℃ were observed. Furthermore in Fig. 5, neither significant decrease in absorbed energy nor increase in hardness was observed at the center of the plate. However, decrease in the absorbed energy with an increase in hardness could be found near both inner and outer edges. The results corresponded to the pre-strain distribution induced by the cold press-bending. The failure cross-section after Charpy impact test is related to the ductility of a material, which is represented by the ratio of brittle failure area over the whole cross-sectional area. The fracture surface showed that no brittle failure could be observed after 365 days of exposure to strain aging under the test temperature of 0 ℃. Conversely, under -60 ℃, a larger ratio of brittle failure was found at the center of the plate. In conclusion, no significant effect of strain aging for SBHS400 was identified. The major factors to prevent toughness loss due to strain aging are the reduced carbon content and fine-grain microstructure of SBHS400. Despite the effect of strain aging, Charpy absorbed energy is able to remain above the required JIS specification 100J[3], which shows the possibility to be cold-formed.

4. CONCLUSIONS

In this study, the effect of strain aging on the cold press-bent structure made of SBHS400 was evaluated by Vickerôs hardness test and Charpy impact test. The effect of strain aging could not be distinctively observed. Moreover, SBHS400 was able to maintain its high toughness, which is considered to be a good fit steel material for cold-forming.

ACKNOWLEDGEMENT

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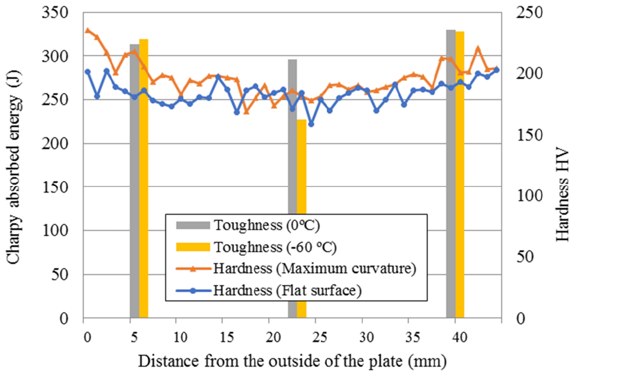
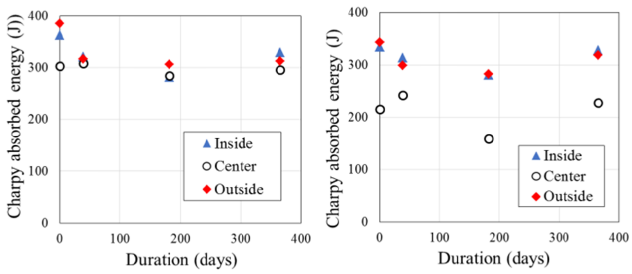


Fig. 3 Vickerôs hardness test



(a) 0 ℃ (b) -60 ℃

Fig. 4 Charpy absorbed energy

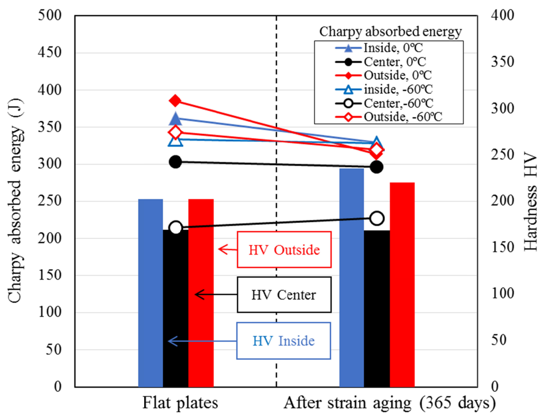


Fig. 5 Charpy absorbed energy and hardness