CHARPY IMPACT TESTS WITH TEST SPECIMENS MADE WITH STOP-HOLE-SIZE CORES

Kiyoshi Ono[1], Kengo Anami[2] and Mitsuharu Oikawa[3]

Abstract

In order to examine or repair fatigue damaged steel bridges, it is necessary to obtain information of mechanical and chemical properties of steel of damaged members or joints. However, for the old bridges, it is sometimes difficult to obtain such kinds of information from design articles. For such case, a sample material might be taken from the structures, but the sample should be as small as possible.

This study examines the use of small steel pieces regarded as cores, which are taken from stop-holes or bolt-holes. Test specimens for Charpy impact test are made with small steel pieces by Electron Beam Weld (EBW) and the effect of the steel piece size on Charpy absorbed energy are examined.

Introduction

Fatigue damage in steel bridges have been reported (Japan Road Association. 2007, 2009; Miki et al. 2007)and the number of reported fatigue damage has increased. Some of the fatigue damage are serious fatigue damage such as the fracture that extended halfway through the circumference of a steel pipe column of a pedestrian bridge and the crack on the web plate of a steel girder whose length is about 1.1m. In order to identify the cause of fatigue damage or examine the retrofitting methods of fatigue damage, it is necessary to gain the information on the mechanical, chemical and fracture properties of materials of steel bridges. Especially as for the old steel bridges, there are some cases that the information about the material does not remain or the standard of the material does not exit at all. In such cases , the test specimens or samples are picked from the base material of steel bridges. For example, test specimens of Charpy impact tests were made with the material removed form the base material and Charpy impact tests were carried out in order to examine the fracture toughness (Miki et al. 2009). However, it is desirable that the area picked from the sound base material is as small as possible.

By the way, there are cases that stop-holes are bored for preventing the crack propagation and the holes for high tension bolts are bored for retrofitting by the bolted splice steel plates. It is very effective and useful to use the stop-hole-cores or bolt-hole-cores as the test specimens or samples.

---

[1] Associate Professor, Dept. of Civil Engineering, Osaka University

[2] Associate Professor, Dept. of Civil Engineering, Shibaura Institute of Technology

[3] Bachelor, Dept. of Civil Engineering, Shibaura Institute of Technology

In order to evaluate the fracture toughness by using stop-hole-size cores, this study examines to make the test specimens with the stop-hole-size cores and conduct Charpy impact tests by using the test specimens. To be concrete, a small steel piece including the V-notch area gained from the stop-holes or bolt-holes is connected to the other parts of the test specimen by electron beam weld (EBW) as shown in Figure1. The effect of the width of the small piece on the Charpy absorbed energy is investigated.

Mechanical and chemical properties of material

One of the major interest of this study is to investigate the material properties of the old steel. Therefore, the steel plates for the test specimens were picked from a web plate at a cross beam of a steel bridge constructed in the 1920's or 1930's and test specimens were made with the steel plates. The plate thickness of the targeted steel plate is 9mm. The information on the material properties does not remain at all. Therefore, the tensile tests and the chemical analysis were carried out in order to get the basic information on the material properties before Charpy impact tests.

Test specimens were removed in longitudinal direction of the cross beam and direction perpendicular to longitudinal direction. The number of test specimens in each direction is three and the total number is six. Table 1 indicates not only the average values of major mechanical properties about the strength and elongation in each direction but also the values specified in the 2008 JIS (Japanese Industrial Standards) as for SS400 that is rolled steel for general structures and SM400A that is rolled steel for welded structures. Figure 2 shows an example of stress-strain relationship gained from the tensile tests. As shown in Table 1, the mechanical properties of the steel satisfy the specifications of SS 400 and SM400A in the 2008 JIS.

Table 2 shows chemical analysis results and chemical components specified in the 2008 JIS in respect of SS400 and SM400A. As shown in Table 1, although the amount of "S" does not satisfy the specification as for SM400A in JIS, the other components in Table 2 satisfy the specifications as for SS400 and SM400A in JIS.

Assumed size of cores

The main purpose of this study to make the test specimens with the stop-hole-size cores for Charpy impact tests in order to evaluate the fracture toughness. Figure 1 shows an outline of test specimen examined in this study. As shown in Figure 1, a small steel piece including the V-notch area corresponding to a stop-hole core or a bolt-hole core is connected to the other parts of the test specimen by EBW. It is assumed that a diameter of the stop-hole or bolt-hole is 24.5mm or 26.5mm. It is thought that the stop-hole-size core whose diameter is 20mm can be obtained from the assumed stop-hole or bolt-hole. Figure 3 shows the relationship between an assumed stop-hole-size core gained from steel bridges and a small steel piece including the V-notch area of a test specimen. As shown in Figure 3, the square steel pieces whose size is 13mm can be gained from the stop-hole-size core whose diameter is 20mm. In consideration of Figure 3, 13mm is decided as the maxim size "B" of square steel pieces gained from the stop-hole-size cores.

Procedure of making test specimens by EBW

The welding condition of EBW used in this study is as follows.
Voltage: 60(kV), Current: 65(mA), Welding speed: 650mm/min.

EBW was carried out from the one side of test specimens. The outline of the procedure of making test specimens is as follows.

- Small steel pieces corresponding the main part of test specimens including V-notch (① in Figure 4), steel spacers (② in Figure 4), edge parts of the test specimens (③ in Figure 4) and the bucking metal are set as shown in Figure 4. The steel grade of edge parts of the test specimens is SM490.
- EBW (Blue solid lines in Figure 4) is conducted.
- Cutting along the yellow dotted lines in Figure 4 is conducted.
- Making test specimens are completed by cutting and shaving off until the predetermined size and thickness of under-size Charpy V-notch impact test specimens specified in JIS.

Types of test specimens

It was impossible to make the standard-size Charpy V-notch impact test specimens whose thickness is 10mm because the thickness of targeted steel plates is 9mm. Therefore, under-sized Charpy impact V-notch test specimens whose thickness is 7.5mm were made in this study. In the case of making test specimens by welding, the influence of welding on the change in the material properties like the heat-affected zone should be considered. Moreover, some previous studies (Seo et al. 1982; Seo et al. 1983) pointed out that Charpy absorbed energy is effected by restriction by EBW and the adequate test results can not be gained if the distance between each EBW is small. Therefore, test specimens were set with focusing on the width of small steel pieces "B" in Figure 5. "B" corresponds to the distance of the center of each EBW as shown in Figure 5. Table 3 shows types of test specimens and the values of "B". In Table 3, the test specimen "B-0" indicates the test specimens without EBW. According to the experience of EBW until now, it is supposed that the width of the heat-affected zone by EBW whose welding condition is almost the same as that in this study may be 6mm. The width of the non heat-affected zone of each test specimens is supposed to be (B-6)mm as shown in Figure 5. Judging from this assumption about the width of the heat-affected zone by EBW, it is estimated that all over the V-notch area of test specimens "B-4" may become the heat-affected zone by EBW.

Macrostructure tests and Vickers hardness tests

Macrostructure tests and Vickers hardness tests were conducted in order to investigate the heat-affected zone by EBW. The weight of Vickers hardness test in this investigation was 9.8N. The location of the measuring points is the center of the height of test specimens and the interval of the measuring points is 0.5mm. Pictures 1 and 2 show the results of the macrostructure tests of the test specimens "B-1" and "B-3". Figures 6 and 7 show the test results of Vickers hardness tests of those. In the pictures and the figures, "Front surface" indicates the surface in which electron beam was discharged and "Back surface" indicates the opposite side. In Figures 6 and 7, read dashed lines express the supposed center of EBW.

According to the results of the macrostructure tests and Vickers hardness tests, it is found that heat-effected zone by EBW on the front surface is wider than that on the back surface because the front surface is a surface in which electron beam was discharged. Judging from the hardness gained from Vickers hardness tests, it is thought that there is a correlation between "*B*" and the width of the non heat-affected zone "*L*", in which the hardness is almost the same as that of the base material. The values of "*L*" are described in Table 3. As shown in Table 3, the values of "*L*" become smaller as those of "*B*" become smaller.

Results of Charpy V-notch impact tests

Charpy V-notch impact tests were conducted with under-sized test specimens whose thickness is 7.5mm. The temperature for the Charpy V-notch impact tests was 0°C, -30℃ and -60℃. Figure 8 shows the results of the Charpy V-notch impact tests. The significant difference in the test results at -60℃ and -30℃ among all test specimens is not found and the values of the Charpy absorbed energy at -60℃ and -30℃ are very small as a whole. On the other hand, the difference in the Charpy absorbed energy at 0℃ can be found depending on the type of the test specimens. The Charpy absorbed energy of the test specimens "B-13" whose "*B*" is 13mm is almost the same as that of the test specimens "B-0" that is test specimens without EBW although the variation in test results can be seen. The Charpy absorbed energy of the test specimens "B-4" in which all over the V-notch area is a heat-affected zone is the smallest of all types of test specimens. The Charpy absorbed energy of the test specimens "B-9" whose "*B*" is 9mm exist between that of "B-4" and that of "B-0" or "B-13". The test results show that the Charpy absorbed energy depends on the width "*B*" and the wider "*B*" leads the higher Charpy absorbed energy. Furthermore, the Charpy absorbed energy of the test specimens "B-13" whose "*B*" is 13mm is almost same as that of test specimens without EBW. Therefore, it is thought that the Charpy absorbed energy of test specimens made by EBW may converge to that of test specimens without EBW when "*B*" is almost 13mm. This fact indicates the possibility that the Charpy absorbed energy can be evaluated adequately with the test specimens made with stop-hole-size cores by EBW.

Concluding remarks

This study examines the use of small steel pieces regarded as cores, which are taken from stop-holes or bolt-holes. The targeted steel is the steel removed from a web plate at a cross beam of steel girder bridges constructed in the 1920's or 1930's. Test specimens for Charpy impact test are made with small steel pieces by Electron Beam Weld (EBW) and the effect of the steel piece size on Charpy absorbed energy are examined.

As a result, it is found that the Charpy absorbed energy depends on the width of the steel pieces and the wider steel pieces leads the higher Charpy absorbed energy and it is thought that the Charpy absorbed energy of test specimens made by EBW may converge to that of test specimens without EBW when the width of the steel pieces is almost 13mm. This fact indicates the possibility that the Charpy absorbed energy can be evaluated adequately with the test specimens made with stop-hole-size cores by EBW.

Acknowledgments

This work was supported by the Grant-in-Aid for Scientific Research (S: No. 18106010) from the Japan Society for Promotion of Science (JSPS).

References

Japan Road Association (2007): Collection of Example of Retrofitting of Highway Bridges. (in Japanese)

Japan Road Association (2009): Collection of Example of Retrofitting of Highway Bridges. (in Japanese)

Chitoshi Miki and Takuyo Konishi (2007): Retrofit Engineering for Steel Bridge Structures in Japan, A-0673, IABSE SYMPOSIUM, WEIMAR, 2007.

C. Miki, K. Ono, K. Yokoyama and T. Harada (2009): Identification of the causes of fracture in the steel pipe column of a pedestrian bridge, Welding in the World, Vol.53(9/10), pp.229-237.

Kenji Seo and Junichi Masaki (1982): Physical Interpretation for the Upper Shelf Energy of Weld Zone in Charpy Impact Test, Journal of the Japan Welding Society, Vol. 51, No.3, pp.39-45. (in Japanese)

Kenji Seo, Junichi Masaki, Fumio Nogata and Kunihiko Sato (1983): Effect of Mechanical Heterogeneity on the Ductile-to-Brittle Transition Behavior of Weld Metal in Charpy Impact Test, quarterly journal of the Japan Welding Society, Vol.1, No.2, pp.123-129. (in Japanese)

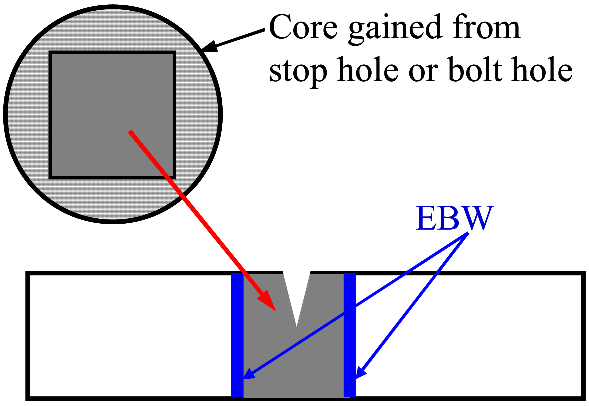


Figure 1 Image of test specimens made with stop-hole-size cores

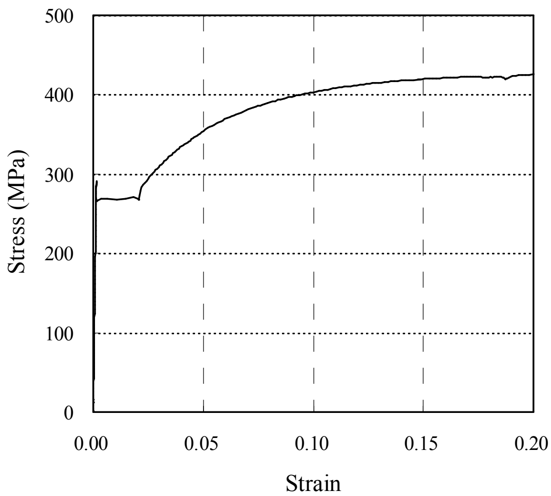


Figure 2 Stress-Strain relationship

Table 1 Mechanical properties

	Direction	Upper yield Stress σ_{yu} (MPa)	Lower yield Stress σ_{yl} (MPa)	Tensile Strength σ_B (MPa)	Elongation δ (%)
Targeted steel	Longitudinal	289	265	428	40.7
	Perpendicular	283	262	424	40.3
SS400(JIS-2008)		≧245	—	400～510	≧17
SM400A(JIS-2008)		≧245	—	400～510	≧18

Table 2 Results of chemical analysis

	C (%)	Si (%)	Mn (%)	P (%)	S (%)
Targeted Steel	0.18	0.01	0.46	0.031	0.038
SS400(JIS-2008)	—	—	—	≦0.050	≦0.050
SM400A(JIS-2008)	≦0.23	—	≧2.5×C	≦0.035	≦0.035

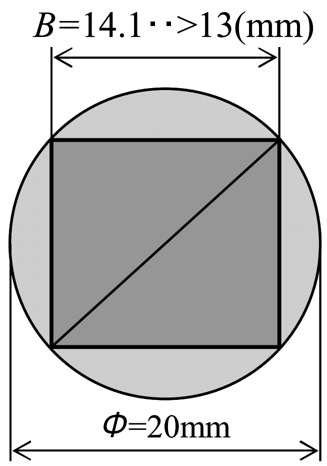


Figure 3 Relationship between assumed cores and gained steel pieces

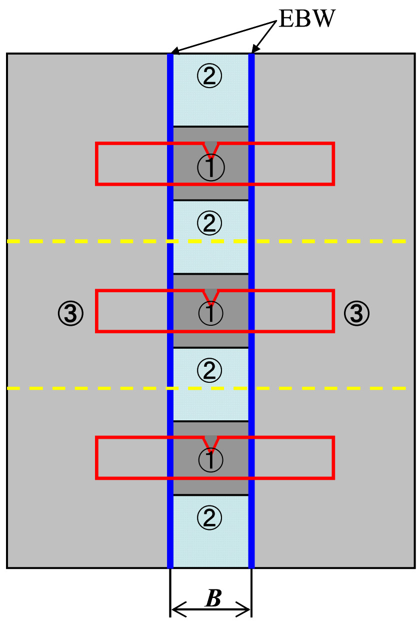


Figure 4 Procedure of making test specimens by EBW

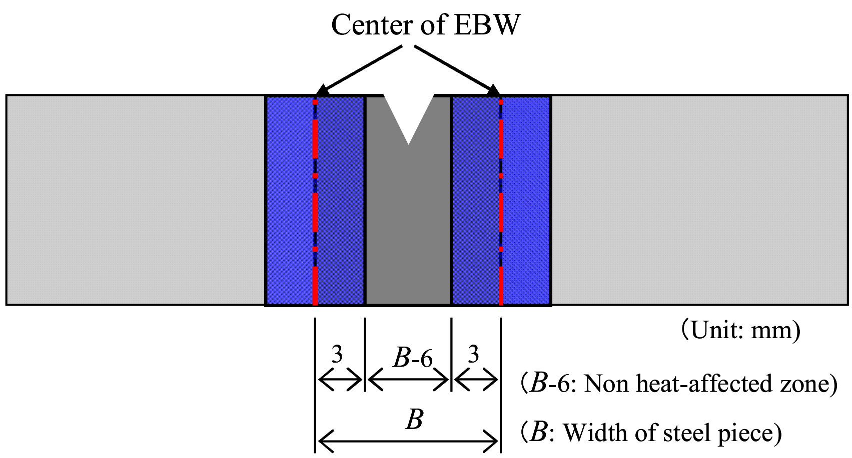
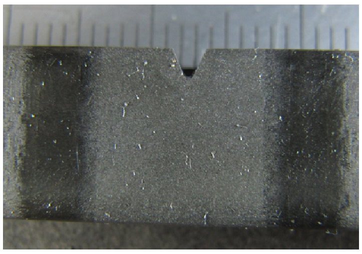


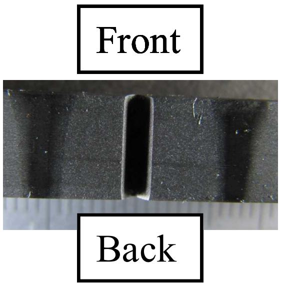
Figure 5 Test specimens made with stop-hole-size cores by EBW

Table 3 Types of test specimens and the values of "*B*", "*B*-6" and "*L*"

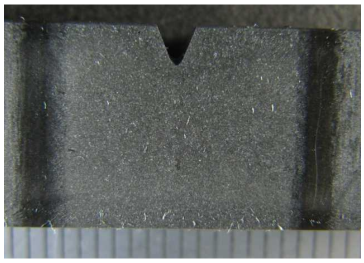
	Width of Steel Piece *B* (mm)	Width of Non Heat-affected Zone			
		Assumuption *B* -6 (mm)	Based on Hardness: *L* (mm)		
			Front	Back	Average
B-13	13	7	8	10	9.0
B-9	9	3	3	4	3.5
B-4	4	- (0)	0	2	1.0
B-0	Non-EBW				



(a) Front surface

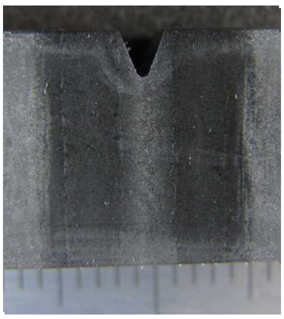


(b) Side surface

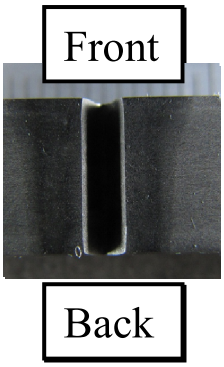


(c) Back surface

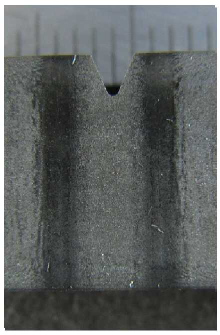
Picture 1 Results of macrostructure tests of test specimen "B-13"



(a) Front surface

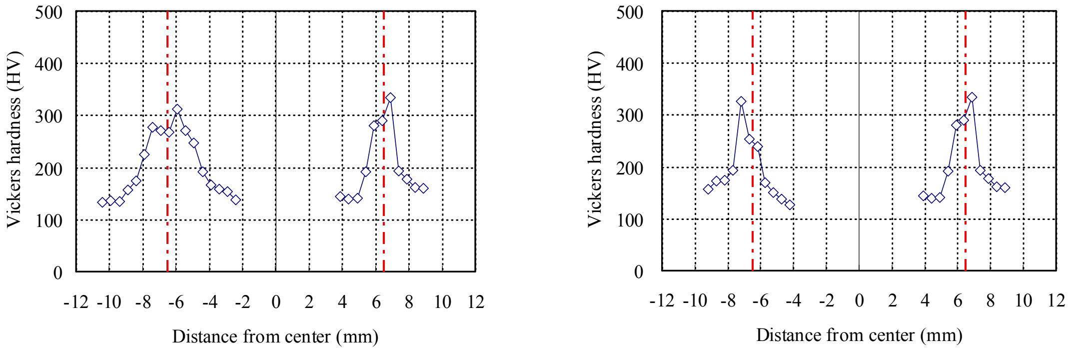


(b) Side surface



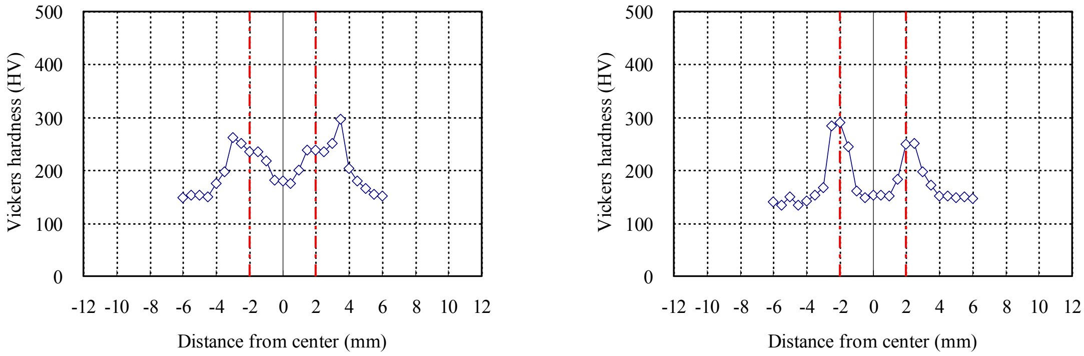
(c) Back surface

Picture 2 Results of macrostructure tests of test specimen "B-4"



(a) Front surface (b) Back surface

Figure 6 Results of Vickers hardness tests of test specimen "B-13"



(a) Front surface (b) Back surface

Figure 7 Results of Vickers hardness tests of test specimen "B-4"

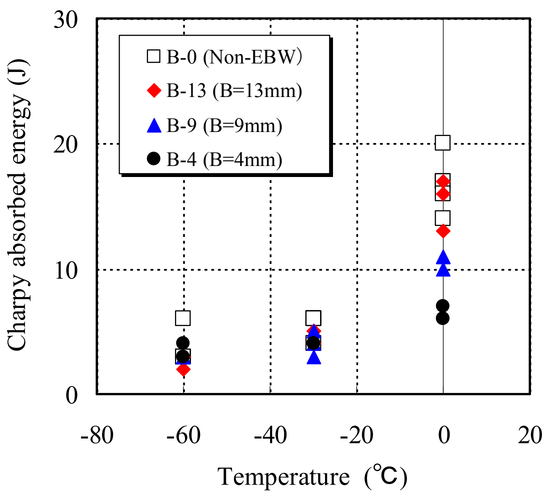


Figure 8 Results of Charpy V-notch impact tests