Implementing Innovative Ideas in Structural Engineering and Project Management
Edited by Saha, S., Zhang, Y., Yazdani, S., and Singh, A.

ISBN: 978-0-9960437-1-7

MEASUREMENT OF RESIDUAL STRESS BY CORING AND MATERIAL TESTING OF MINUTE TEST PIECES

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In this research, the distortion resulting from stress relaxation was measured by opening a core with strain gauge, which was attached to several places of a full-scale steel beam, and the residual stress was calculated from the measured strains. This research summarized and compared the calculated residual stress distribution. In the material testing using the minute test piece for grasping mechanical characteristics, tensile test and Charpy impact test were conducted. In these each two experiments, two kinds of minute test pieces with different dimensions and joining method that assumed to be manufactured by a core about 20 millimeter in diameter were used. In tensile testing, this study shows that the reduction in board thickness direction, shape of the specimen and initial strain affect the strength and Young's modules. In Charpy impact testing, this study shows that it is possible to obtain correct Charpy absorbed energy by using welded specimen.

Keywords: Stop-hole method, Patch repair method, Tensile testing, Charpy impact testing.

1 INTRODUCTION

1.1 Background and Methodology

The stop-hole method, in which a hole is drilled at the tip of crack to eliminate the stress concentration, is known as one of the methods for preventing the crack extension of steel plates. In this method, after coring the tip of crack, the fatigue strength is improved by tightened with a high strength bolt. Compared with a conventional method such as cutting off and replacing the damaged parts or members, the stop-hole method has more advantages in the viewpoint of cost and time. Moreover, it is very useful for an estimate of the damage with the deterioration of steel bridge that is thought to be increased in the future, if it is possible to grasp the basic mechanical property of steel materials from the core collected by the stop-hole method and the patch repair method.

In this research, the following two experiments were conducted focusing on the core provided by the stop-hole method and the patch repair method for the purpose of the measure of the fatigue damage:

(1) The measurement of the residual stress in the steel beam by coring

(2) The material test of the specimen created by a sample of the size of the core

The flow of this research is shown in Figure 1.

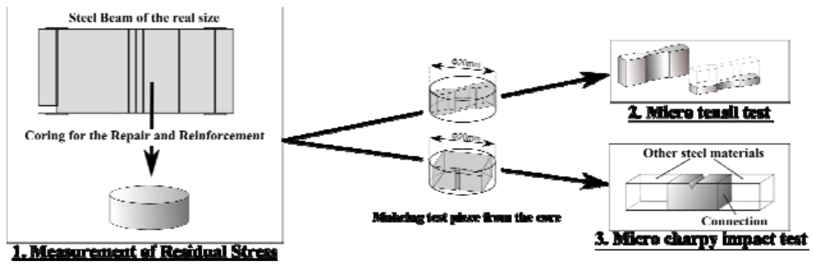


Figure 1. Research flow.

In the measurement of the residual stress, the released strain caused by drilling the core was measured by the strain gauges installed to the both sides of plate. And distribution of the residual stress exchanged from the measured strain is compared with the typical residual stress distribution produced by the welding.

In each material testing using minute test piece, tensile test and Charpy impact test were conducted for grasping mechanical characteristics. Based on the experimental results, the influence of the difference of dimensions and of connecting method of the specimens on the tensile strength, yield strength, and Charpy absorbed energy is discussed by comparing the results of using Japanese Industrial Standard specimen[a)].

2 MEASUREMENT OF RESIDUAL STRESS IN STEEL BEAM BY CORING

2.1 Summary of the Experiment

The dimensions of the test specimen and the position where a strain is measured are shown as Figure 2.

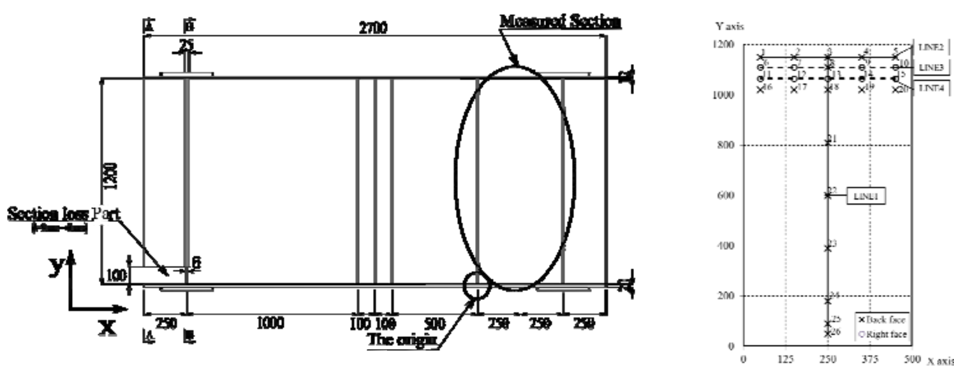


Figure 2. The dimensions of the test specimen and the position where a strain is measured.

In the measurement of the residual stress, the strain caused by the release of the residual stress by coring the steel beam is measured by the strain gauge pasted on the web. In the case of measuring the strain in the back side of the steel beam, the gauge is pasted on the back side of the steel beam and the core is taken off from the right side of it. In consideration of the heat generated by coring, the strain was measured after taking enough time. In addition, the inside diameter of the blade of the drill (jet broach) used for coring is 19.5 mm, the outside diameter of it is 24.5 mm.

About the conversion of strains to the residual stress, each residual stress is obtained by substituting measured released strains for ε in the Eq. (1) or Eq. (2), where σ_x and σ_y are residual stresses in X axial direction and Y axial direction, ε_x and ε_y are released strains in X axial direction and Y axial direction, respectively. E is the Young's modulus of steel beam, ν is Poisson's ratio.

$$\sigma_x = \frac{\mathrm{E}}{1-\nu^2}(\varepsilon_x + \nu\varepsilon_y) \qquad (1) \qquad\qquad \sigma_y = \frac{\mathrm{E}}{1-\nu^2}(\varepsilon_y + \nu\varepsilon_x) \qquad (2)$$

2.2 Results and Discussions

The distribution of the residual stress of each direction calculated from released stress by coring is shown as Figure 3. From the figure, it is found that compression stress occurs generally and tensile stress hardly occurs except at the edge among a flange and a stiffener. In the typical residual stress distribution by the welding, tensile stress is thought to be occurred in the vicinity of the welding part. However, as for LINE1, compression stress occurs in all positions from the vicinity of the weld part of the upper flange part to the bottom part. It is thought that this is because there is little influence by the welding of the top and bottom flange or the compression strain was given by the loading to the test specimen. Also, it is thought that the slip occurs at the adhesive layer of the strain gauge by the heat generated while coring.

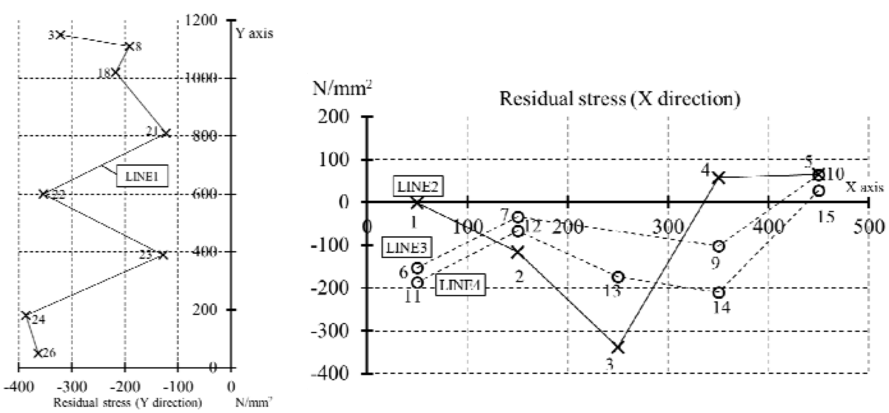


Figure 3. Distribution of the residual stress.

3 MICRO TENSILE TESTING

3.1 Summary of the Experiment

The shape and dimensions of the test specimen used in this study are shown as Figure 4 and Table 2. The specimen was made from SS400 grade steel with 9mm thickness. Three cases of tensile test in total were conducted, where M-1 and M-2 specimen whose all the dimension except for the thickness is equal to NO.5 specimen (approximately a one- tenth size). The dimension of M-1 and M-2 are decided as the maximum size which can be collected from the core with a diameter of 20 mm by the stop-hole method and the patch repair method.

To examine the influence of the plate thickness, the specimens of thickness 9 mm and 3 mm are prepared. The thickness of M-1 specimen remains 9mm. And M-2 specimen whose thickness is 3mm is made by machining taking into account of the influence of eccentricity.

When the specimen is attached to the gripper of the equipment, it was assumed that the strain would be generated in the specimen by tightening a specimen in the thickness direction and the gap of the gripper. Therefore, the strain is measured and the load is controlled so that the initial deformation does not occur, while setting the specimen.

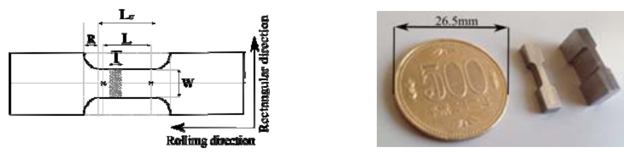


Figure 4. The shape of the specimen.

Table 2. Test specimen dimensions (Unit: mm).

Specimen	Thickness T	Width W	Gauge length L	Parallel portion length L_c	Radius of fillet R	Name
NO.5	9	25	50	60	15	-
M-1	9	2	4	4.8	1.2	(a),(b),(c),(d)
M-2	3	2	4	4.8	1.2	(e),(f),(g)

3.2 Results and Discussions

Results of each specimen are shown as Figure 5. The initial strain generated by tightening a micro specimen in the equipment is shown Figure 6.

As for tensile strength, the value of M-2 specimen is nearly equal to that of NO.5 specimen, but the value of M-1 specimen is slightly larger than that of NO.5 specimen. Considering that the dimensions of M-1 and M-2 specimen except for the thickness are equal to each other, it is thought that the shape of the specimen having the thickness extremely larger than the parallel portion length affects tensile strength.

As for yield strength, the value of M-1 specimen is almost equal to that of NO.5 specimen, but the value of M-2 specimen is much smaller than that of NO.5 specimen. In addition, a clear yield point did not appear in the case of M-2 specimen. From this result, the reduction of thickness influences on the initial plastic deformation.

As for Young's modulus, like the result of yield strength, the value of M-1 specimen is almost equal to that of NO.5 specimen and the value of M-2 specimen is much smaller than that of NO.5 specimen, but there is a dispersion in the same case. The specimen which has lower Young's modulus compare to other specimens in the same case ((a), (d), (g) in Figure 6) has higher initial strains more than that of other specimens. From these result, it is thought that Young's modulus is affected by the thickness of the specimen and the initial strain.

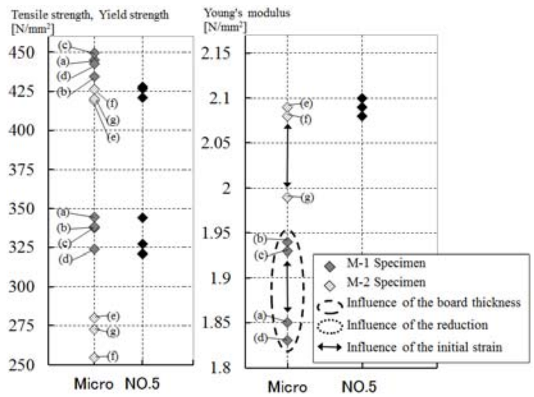


Figure 5. The results of each specimen.

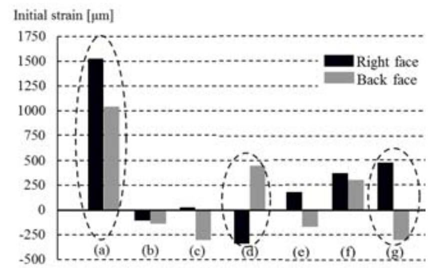
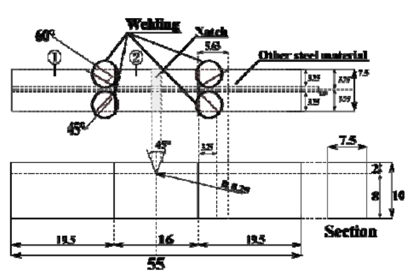


Figure 6. The initial strain.

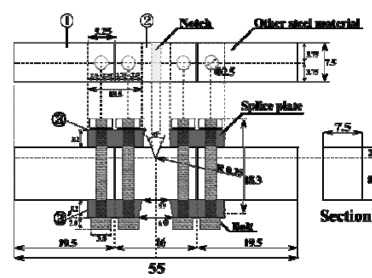
4 MICRO CHARPY IMPACT TESTING

4.1 Summary of the Experiment

The width of the support of Charpy impact testing equipment prescribed in JIS Z2242 is 40 mm, and this is bigger than the diameter of the core assumed to be obtained by the stop-hole method and the patch repair method. Therefore, it is necessary that the micro specimen made from the core is connected to other steel materials (hereinafter, called as the length adjustment board) and extended to set the testing equipment in conformity with the Japanese Industrial Standards.



(a) S-2 specimen.



(b) S-3 specimen.

Figure 7. The dimension and the shape of micro Charpy specimens.

Therefore, in this research, two types of the Charpy specimens are prepared as shown in Figure 7. Figure 7 shows the dimension and the shape of each material of experiment test specimen. Three cases of Charpy impact test in total were conducted, where V notch specimen prescribed in JIS Z2242 and two kinds of specimens whose length adjustment boards are connected by using bolts or a butt weld. In the following, V notch specimen used to support the comparison is expressed as S-1 specimen, the specimen used a butt welding connection is expressed as S-2 specimen and the specimen used bolt connections is expressed as S-3 specimen.

4.2 Results and Discussion

The results of S-1 and S-2 specimen and the shape of the broken surface are shown as Figure 8 and Figure 9.

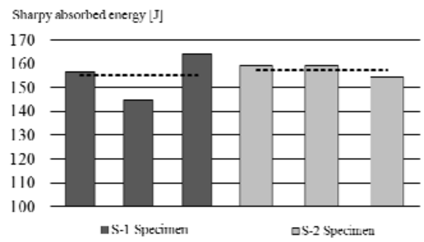
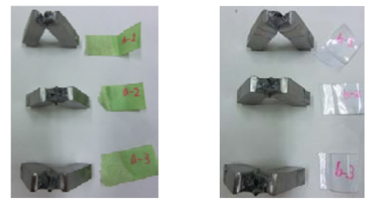


Figure 8. The result of S-1 and S-2 specimens.



(a) S-1 specimen. (b) S-2 specimen.

Figure 9. Shape of broken surface.

For the S-2 specimen, Charpy absorbed energy is provided at the same level of S-1 specimen. Also, the difference between S-1 and S-2 specimens is not visible on the broken surface. It is thought that the number of passes used in the Tig welding is so few that the specimen suffers little influence of the heat at the time of the processing. From these results, it can be concluded that it is possible to measure the correct Charpy absorbed energy by using the micro specimen which is made by a general welding method such as Tig welding.

As for S-3 specimen, the correct Charpy absorbed energy is not provided because a gap occurs between the specimen and the splice plate, and then bolts are broken before breaking the specimen. There is no possibility that a hammer collide with a splice plate so that the specimen does not break because there is a collision trace to the central specimen with a notch.

5 CONCLUSIONS AND FUTURE POLICY

It is possible to calculate the residual stress by coring for the measurement of residual stress in steel beams. However, considering the results, by comparing the typical residual distribution, it is necessary to investigate the effect of coring, especially the effect on the strain gauge due to the heat dissipated.

For the micro tensile testing, the reduction in board thickness direction, the ratio of the parallel portion length to thickness affects the tensile strength and yield point. Initial strain affects the Young's modules. To examine the influence of these parameters, it is necessary to consider how to process the surface of the specimen and the thinning method.

For micro Charpy impact testing, it is possible to obtain correct Charpy absorbed energy by using welded specimens influenced by the welding before testing.

References

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