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EVALUATION ON ELONGATION OF REBAR BY USING IMAGE PROCESSING METHOD

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In this study, longitudinal strain distributions of rebars in the uniaxial tension test are evaluated with an image processing method (IPM). The measurements of strain are conducted till rebar is ruptured. As a result of the test, the detailed longitudinal strain distributions of rebar in the tension test are clarified and the results show that the strain at necking region are almost 2-3 times of average strain in the gauge length of specimen. After the stress of rebar is reached at ultimate strength, the most of elongations are concentrated at necking region. In the other region except necking region, therefore, the strains are merely increased till the end of test. From these results, it is estimated that the necking region can make the over estimation of elongation of rebar, therefore, the estimation except the necking region can be suggested to evaluate the true elongation of rebar. Also the measured results with IPM are compared with the measured results by using conventional strain gauge. It is estimated that the IPM shows some noise in data, but the IPM has advantages to measure the strain distribution to the range of rupture. Therefore if the image acquisition of the better resolution and better quality are possible, it can be a good alternative measuring method for the strain measurement.

Keywords: Stress-strain relationship, Ultimate strain.

1 INTRODUCTION

When evaluating the strain of the rebar, strain gauge or extensometer is usually used. The strain gauge is used in various structural experiments. It is attached to a certain point and gauges strain at that point. The weakness of the strain gauge is its limited gauging range (under 20%) and the complexity, time, and cost required in attaching the gauge. Extensometer, on the other hand, measures the overall displacement of the section where the extensometer is installed and convert it to strain. Therefore it is difficult to measure the distribution of strain over the section with the extensometer. To overcome such weakness of existing methods, many studies are being conducted. Many researchers use image processing when measuring strain.

In this study to overcome limitations and disadvantages of the conventional strain gauge and extensometer, image processing method with rigid targets on the specimen surface are used for an uniaxial tensile test of rebar. The image processing method is conducted with an in-house code to recognize position of targets in the frames and to calculate the strain based on the differences of location between every target. Also the red targets are used to improve recognition rate of targets. To evaluate the applicability of the image processing method for the measurement of rebar strain, the measured strains are compared to the results from the conventional strain gauges.

2 IMAGE PROCESSING METHOD (IPM)

Image processing is a kind of signal processing which is related with an image from camera. The image processing can convert an image to emphasize characteristics or can analyze patterns in the image (Cintron 2008; Barranger *et al.* 2012; Germaneau *et al.* 2008). In this study, image processing with red-colored rigid targets is used to measure local strains and strain distributions of rebar in uniaxial tensile test. Figure 1 shows the algorithm of the image processing method used in this study. Overall process in the IPM is conducted with MATLAB. First, the benchmark targets are selected in the obtained image and then information about the color of the targets is collected. Using the color information, the targets are distinguished logically from its surroundings and converted to a binary image. Next, a centroid of each target range is obtained. By repeating this process throughout the test, displacement between targets, dL, based on the centroid of each target, is calculated. And based on the early target distance, strain of each range is calculated. Here, the strain is a non-dimensional quantity of change and thus the dL can be calculated using the number of pixels in the image, instead of the actual quantity of change in the distance between targets. Therefore, for this measuring method, it is more important to get a high-resolution image than to precisely recognize the scale of the image and the actual object. This study used a camera with 16 mega pixels.

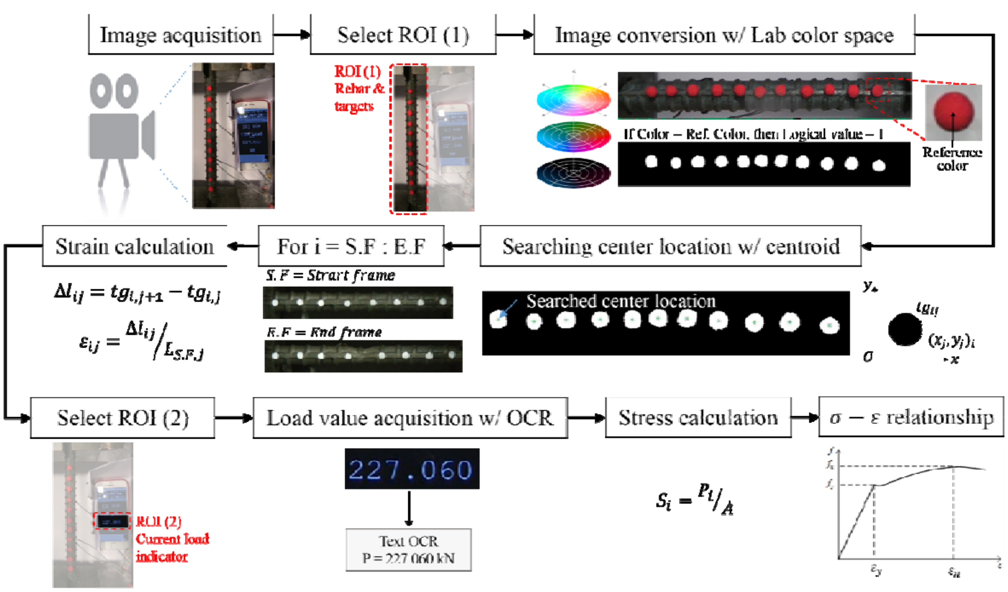


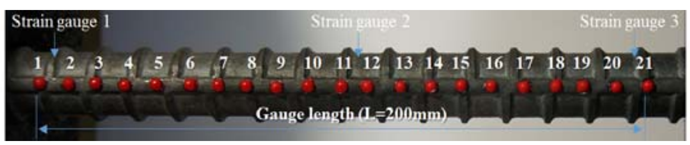
Figure 1. Algorithm for the image processing using colored target.

In this study, the load of the Universal Testing Machine (UTM) is contained in the camera frame and during the post-processing, the load value captured in the image is analyzed with the Optical Character Recognition (OCR) function so that the load value of the image can be obtained. Through such process, the stress-strain relationship of rebars is obtained.

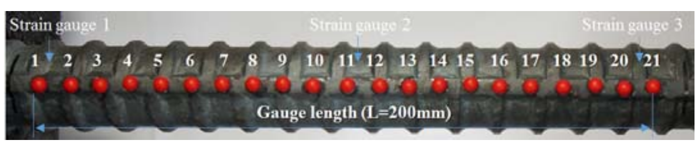
3 TENSILE TESTS FOR REBAR WITH IPM

3.1 Details of Experiments

In this study the strain distribution of the rebar is evaluated through uniaxial tensile tests. The variable for tensile tests is rebar diameters, D22 and D29. The rebars are manufactured as ASTM A 615 standard, and in case of type of material, grade 60 is used. The tensile tests are conducted in accordance with ASTM A 370 standards. Figure 2 shows the specimens on which the targets and strain gauges are attached. A total of 21 targets were attached in the gauge length, with about 10 mm spaces between each. The test results are used to analyze and compare the effect of the rebar diameter on the longitudinal strain distribution and stress-strain relationships of rebar. Also the results from image processing method are compared to the results from conventional strain gauges. Per specimen, three strain gauges were attached on the surface opposite the target attachment as marked in Figure 2. Figure 3 shows the necking occurred in the rebar right before rupture. It is estimated that the necking region in the rebar is almost 2-3 times of rebar diameter.



(a) D22 rebar.



(b) D29 rebar.

Figure 2. Targets and strain gauges position on specimens.

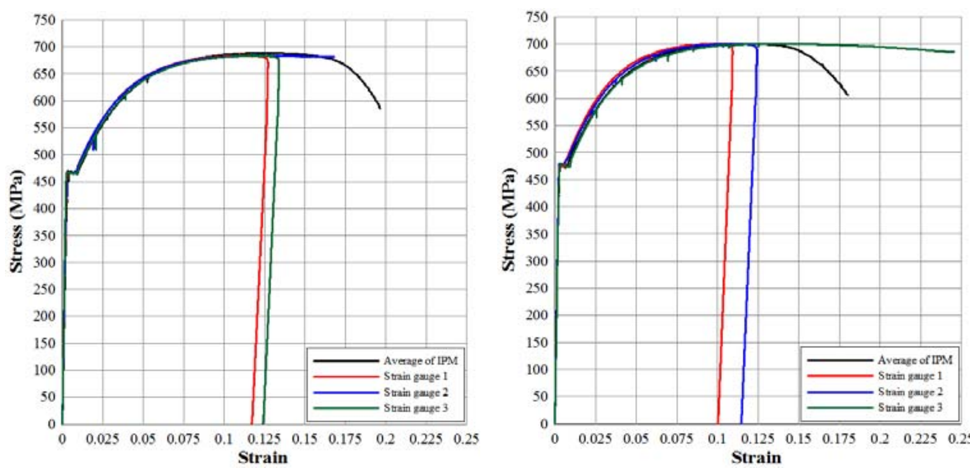
(a) D22 rebar.

(b) D29 rebar.

Figure 3. Necking before rupture.

3.2 Comparison between the Conventional Strain Gauge and IPM

For the comparison of the results by using the conventional strain gauge and the IPM, Figure 4 shows the stress-strain relationships of specimen. The average is the result which is measured with the IPM between T1 and T21. The strains measured with the conventional strain gauge are not reliable after the yield state because the measured strain are not enough to define the ultimate strains of rebars due to the limit of measuring capacity of the conventional strain gauge. The maximum strain measured with strain gauge in this study is 0.245 in the D29 specimen. But in most of the other cases, the strain gauge was ruptured at about 0.1~0.15. That means the conventional strain gauge shows reliable results until the strain reaches around 0.05, but it becomes unreliable when the strain goes over 0.1.

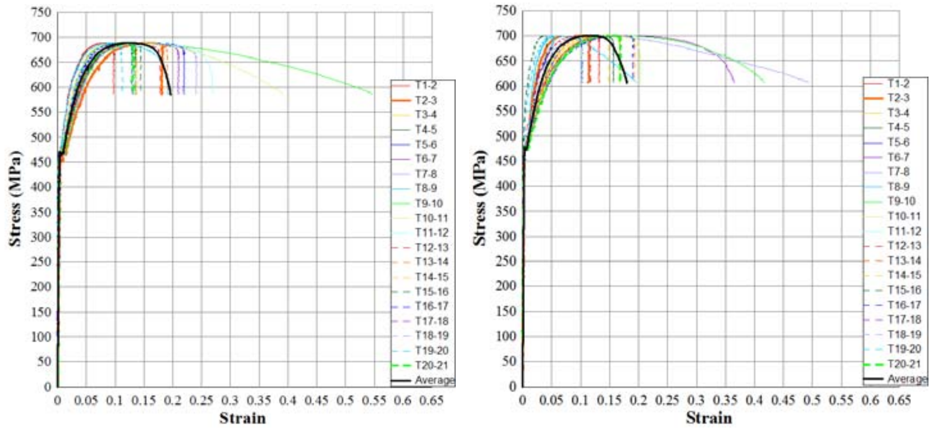


(a) D22 rebar (b) D29 rebar

Figure 4. Comparisons between the conventional strain gauge and the IPM.

3.3 Stress-Strain Curve from the IPM

Figure 5 shows the stress-strain relationships of specimens and test results which are measured with the image processing method. The ultimate strength of D22 and D29 are 686.5 MPa and 700.6 MPa, respectively. Both rebars showed necking after the stress reached the ultimate strength. It was confirmed that when the rebar ruptures after the necking, the strain was concentrated at the necking region and in the other regions, the increase of strain was minimal. It was also confirmed that, except in the necking region in Figure5, there was no change in the strain. The maximum strain was 0.54 for D22 and 0.49 for D29.

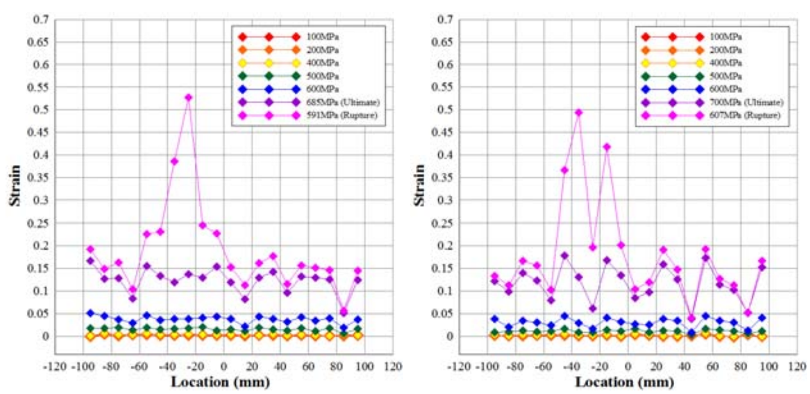


(a) D22 rebar (b) D29 rebar

Figure 5. Stress-strain relationship obtained with the IPM.

3.4 Longitudinal Strain Distribution

Figure 6 shows longitudinal strain distributions by stress status of rebars which are measured by the IPM. Both D22 and D29 showed relatively steady increase in strain until the ultimate stress. But, as shown by the stress-strain curves, strain increased sharply at necking region right before rupture. The length of necking region was calculated by using the strain distribution right before the rupture stress. It is found that, in D22, the length of necking region is around 50mm, while in D29, it is around 60mm, both showing necking in around 2-3 times of diameter region.



(a) D22 rebar. (b) D29 rebar.

Figure 6. Longitudinal strain distribution obtained with the IPM.

4 CONCLUSIONS

The purpose of this study was to observe the strain and ultimate behavior of the rebar, using image processing. For the image processing, red targets were attached with the equal distance between one another and, using the digital camera in the test, the strain of the targets was calculated. The results from the IPM were compared with the results from the conventional strain gauge to evaluate the accuracy and applicability of the IPM. In the uniaxial tensile tests, D22 and D29 rebars were used, which are grade 60 rebars produced according to ASTM A 615 standard. The conclusions obtained from this study are as follows.

First, it was observed that the conventional strain gauge is capable of measuring range 0.1-0.15 strain. On the other hand, the IPM could measure more than 0.5 strain. Also it was able to measure the strain of the necking region of the rebar until rupture. Second, the length of necking region was estimated with the strain distribution before the rupture stress. It is found that, in D22, the length of necking region is around 50mm, while in D29, it is around 60mm, both showing necking in 2-3 times. Lastly, the elongation which is obtained based on the gauge length can be overestimated because the average strain in the gauge length contains the strain at the necking region. Therefore if the IPM is used to measure the elongation of rebar, it can be able to evaluate more practical results than the results with conventional method.

To solve the problem related with the errors due to the low resolution of images, the study with the better quality images which are obtained from higher resolution camera should be conducted in the future works.

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