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8—2 Cracks and Displacement Feature Extraction of the Concrete Block Surface

Soo Hyun Cho, Kensuke Hisatomi, Shuji Hashimoto

Department of Applied Physics,
School of Science and Engineering, Waseda University, Tokyo, Japan

Abstract

An efficient measure of the concrete block structure inspection is needed with the increasing demand for concrete blocks. Cracks in the surface of RC member's can be used as a useful measure of quake-proofness of a construction or material fatigue. Specialists used to observe the cracks and experimentally inspect the structures, while applying destructive forces to the blocks. This paper proposes an automatic detection and analysis system for the concrete block inspection. By employing a high-resolution camera, cracks and displacement features are automatically extracted with image processing techniques, which are considered to be efficient for assisting specialists in the inspection procedures

1. Introduction

Recently Ferro concrete has been widely used in varieties of field. Therefore the need of concrete safety inspection is increasing. At present the general method for inspection of concrete block structures depends only on the specialists' knowledge and experience. It is important to develop an efficient and economical technique for diagnosing concrete structure. The objective of our study is to propose an image processing technique that can efficiently support the diagnosis. A high resolution CCD camera is used for cracks and displacement inspection of the RC structures by employing the image processing techniques.

address: 55N-4-10A, 3-4-1, Okubo, Shijuku-ku, Tokyo, 169-8555, Japan.
E-mail : cho@shalab.phys.waseda.ac.jp
E-mail : hisatomi@shalab.phys.waseda.ac.jp
E-mail : shuji@shalab.phys.waseda.ac.jp

2. Measurement Method

2.1 Crack Extraction

The thickness of concrete crack varies one from another. It is difficult to detect cracks vividly in a noisy surface like concrete. We tried to determine and analyze the directions and shapes of the cracks from images taken in the actual experiment site. The image of concrete is taken by CCD camera and the crack extraction is done by computer image processing. The flow chart of the developed system is shown in Fig.1. The proposed method consists of the following steps.

Step 1 : Image acquisition

A linear scan high resolution CCD camera (Nagase SC-2000) is used to photograph the surface of concrete block. The dimension of the concrete block surface is approximately 100cm×40cm, while the resolution of the CCD camera is

4096×4096 pixel in 256 gray scale.

Step 2 : Shading correction:

The unevenness of lighting that occurs in photographing is removed from the photograph of concrete surface using the background data taken by setting a white board.

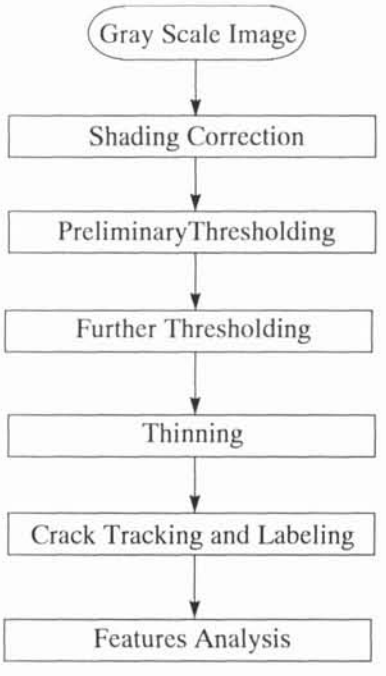

Fig1.System Flow Chart

Step 3 : Preliminary thresholding

The shading corrected image is converted into a binary image using a fixed threshold value. A black pixel of which gray level is smaller than the threshold is regarded as a crack.

We assume that if there exist more than 72 black pixels in the 9×9 pixels around the black pixel, then it is probable that an undetected crack exists in the area.

Step 4 : Further thresholding

A fine thresholding is employed for an area chosen in the preliminary thresholding. As the cracks intermingled with the background in such area, we use the gray level histogram to separate then. Usually, two peaks appear in the histogram, by setting a threshold value k to the intermediate of the peak gray levels, we can distinguish the cracks from the background. We employed the discrimination analysis method for the cracks - background separation. By setting a certain threshold k, the pixels are classified into two categories with respect to the gray level. They are the class1 of which gray levels are less than k and the opposite class2.

Let $\omega_1(k), \omega_2(k)$ represent number of pixel in class1 and class2 respectively, $M_1(k)$ and $M_2(k)$ are averages of brightness in class1 and class2, and $\sigma_1^2(k), \sigma_2^2(k)$ are variances of brightness in the respective class, then the inner class of variance is defined as,

$$\sigma_w^2 = \omega_1\sigma_1^2 + \omega_2\sigma_2^2 \qquad (1)$$

and the inter class variance is defined as,

$$\sigma_B^2 = \omega_1(M_1 - M_T)^2 + \omega_2(M_2 - M_T)^2 = \omega_1\omega_2(M_1 - M_2)^2 \quad (2)$$

where M_T is the total average of brightness. The aim of this method is to determine k, so that, σ_B^2 / σ_W^2 will be maximized.

Step 4 : Thinning

The thresholding is done to extract the length and thickness of a crack. However, to extract the geometrical structure or direction of a crack, a thinning procedure has to be employed to reduce the crack width to 1 pixel size. In this step, iteration of merging two black pixels next to each other is done until the thickness become 1 pixel without altering the connectivity.

Step 5 : Crack labeling

In this step, after a starting point of a crack is detected, the crack is traced until the ending point is detected and then labeled. Data about the distribution of crack angles is obtained for each crack. The example of the crack division labeling is shown in Fig.2.

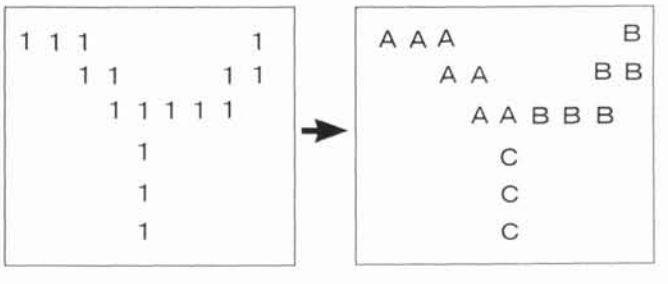

Fig.2 Example of Labeling

Step 6 : Features extraction:

From data obtained in the previous steps, the angle and dimension of cracks is calculated. The distribution of cracks are also analyzed in this step.

a) Crack length - In the labeling process, each crack was followed one pixel by one pixel from its edge to edge. So the length of a crack can also be obtained simultaneously from the labeling process.

b) Crack direction - The definition of crack direction mentioned in this paper is the angle of a crack with respect to

the horizontal axis of the image. However, we can not obtain the direction of the crack by simply using starting point and ending point, because the crack may have many turns. To obtain the direction, the crack has to be divided into some segments, and the direction of each segment must be measured.

c) Crack thickness - It is difficult to obtain the exact thickness of a curved crack. We defined that thickness in the number of pixels omitted is the in the thinning process.

Step 7 : Features analysis and description

We also examined a way to show the features of cracks clearly. The most important aim of proposed method is to extract features of cracks that cannot be presented by the traditional hand sketch, along with an automatic measurement and analysis of cracks. The following crack feature representations are employed in our system.

a) Cracks straight line expression - Using the crack edge coordinates obtained in labeling process, the segments of a crack are approximated with straight lines. With this segmentation the whole crack structure can be presented naturally.

b) Angle histogram - In the labeling process direction and length of each crack's segment can be obtained From this information, the direction of a crack as whole can be extracted using angular density histogram as shown in Fig.3.

c) Thickness histogram-With the same method as (b), thickness density histogram can be obtained as shown in Fig.4.

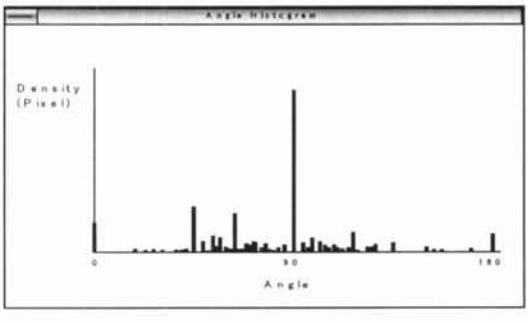

Fig.3 Angular Density Histogram

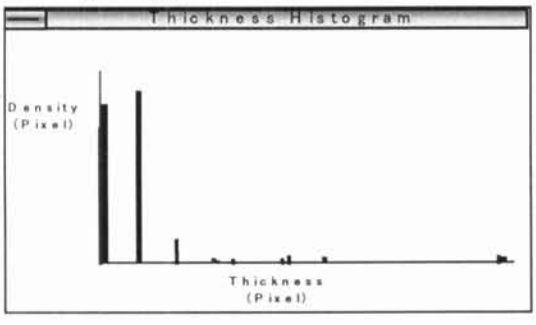

Fig.4 Thickness Histogram

2.2 Displacement Vector Using Optical flow

In our experiment, the images of each step of the loading test of the concrete block surface were photographed and partial displacements are analyzed using motion vectors. To photograph the object, a CCD camera is fixed at a certain angle and position, then the images were taken under the constant light condition during loading test to observe the strain against the load. The concrete surface displacement are measured by using the gradient method.

3. Measurement and Results

3.1 Crack Extraction

Fig.5 shows a typical input original image, Fig.6 shows the binary image and Fig.7 shows the thinning result. Using these images, the mechanical property of the object can be retrieved.

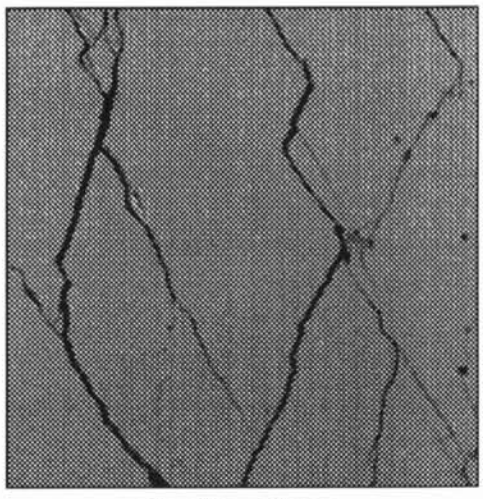

Fig. 5 Input Image

Fig. 6 Binary Image

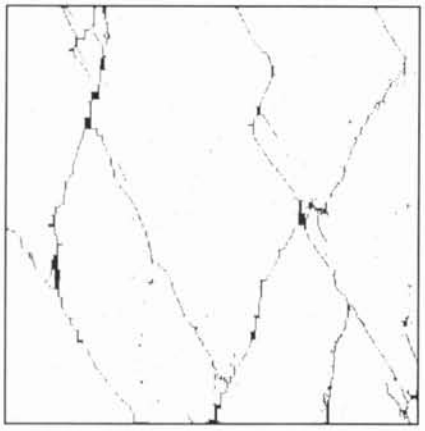

Fig. 7 Thinning Image

In our experiment, the time required to process the all the procedures above may very according to the condition of crack, it is however less than 40 minutes. 80% of processing time is used for thresholding. The proposed method have advantages over the conventional sketching in processing time, precision and cost, However we can still improve the proposed method by reducing its processing time, so that it can be used in real time.

3.2 Displacement Vector Extraction

Optical Flow was yielded using 2 of 6 images taken with different loads during the loading test.

Fig.8 shows an image of block before stress was applied. Fig.9 shows the image with the load of 11.4ton. The motion vector are calculated in every 8×8 pixels area of those images.

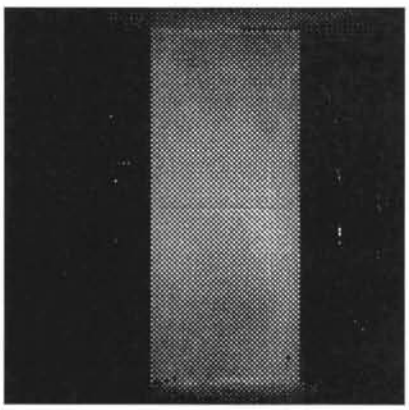

Fig. 8 Image before Loading

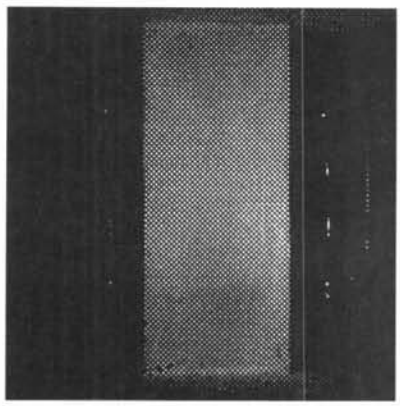

Fig. 9 Image after Loading

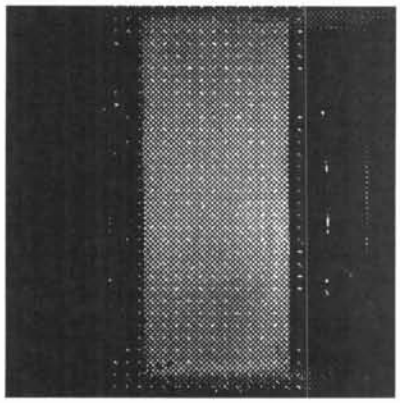

Fig. 10 Displacement Vector

The Fig.10 shows the calculation result of the displacement direction and distance of the concrete material caused in the loading test.

4. Summary

By using high-resolution CCD camera to photograph the object from a distance of 1.2m, the requirement of extraction of 0.04 mm width crack can be fulfilled using the proposed method. The Extraction of displacement with similar accuracy can also be achieved. The proposed measurement system was tested by the professional inspectors and obtained promising evaluations.

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