SEGMENTATION OF AGGREGATE BY EDGE DETECTION IN MORTAR

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1.Introduction

Aggregate is usually considered as a structural filler in concrete. However, actually, its role is much more important than that. Many properties of concrete such as workability, strength, weight are closely related with mechanical properties of aggregate itself. Numerous studies have been carried out for evaluating volume and shape parameters of aggregate using digital image processing. Yang and Buenfeld[1] have used backscattered electron (bse) images for aggregate segmentation. For analysis of microstructural features such as porosity and unhydrated cement which have distinct brightness, their algorithm is effective. The volume fraction of sand in concrete was used as a test parameter for evaluating the algorithm. Fang and Labi[2] have used color thresholding for evaluating static segregation resistance of hardened self-consolidating concrete from color images of cross sections. However, since aggregate have a wide range of colors, the algorithms based on gray scale thresholding and hue discriminating are not proper to aggregate segmentation in concrete.

In this study, a different algorithm based on Canny edge detector is proposed for discriminating aggregate from color images of cross sections of mortars. The volume fractions of aggregate estimated by this algorithm are compared to the real values in mix proportions.

2.Computational Method

1) Specimens

Cement mortar specimens of 4×4×16 cm in size were made from ordinary Portland cement (density : 3.15 g/cm^3, specific surface area: 3310 cm^2/g) and a river sand (density : 2.61g/cm^3) with the ratio of water to cement of 0.65. Only the ratio of sand to cement was changed by 1:1, 2:1 and 3:1 in mass. Volume fractions of sand in the mortar specimens were 28.3%, 42.1% and 54.2%, respectively.

After 28 days of water curing at 20°C, each specimens was cut to obtain ten cross sections. They were ground and polished by abrasive papers at grades of #220 to #1200. Images for the whole cross sections were taken by a scanner of 800dpi. Size of 1 pixel was 31.75μm.

2) Aggregate segmentation method

The procedure to detect aggregate from an image of a cross section is shown in Fig.1. Here, in smoothing operation step, a non linear edge preserving filter was used to remove noise in images. In non maxima suppression step, detected edge lines were labeled to make groups of edge lines, which have the same label. These groups were then connected to a convex hull made through all end points of them, for closing edges.The groups, which have more than two edge points on two sides of color image, were connected to a convex hull passed through all the end points and the intersection point of two image sides. Then, operation of filling holes was used to make binary images of aggregate.

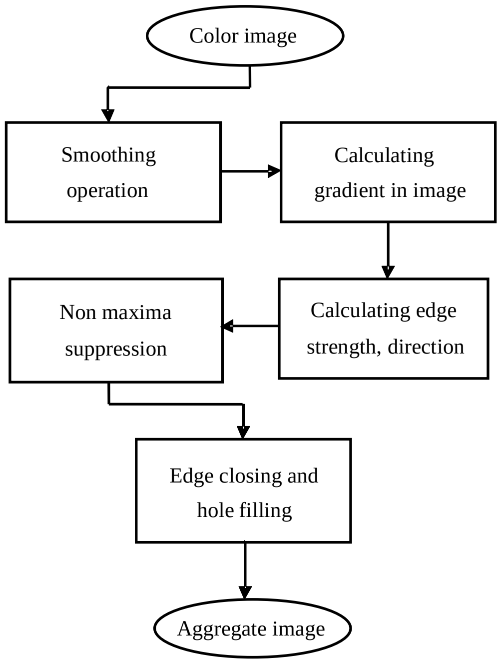

Fig.1 Flow chart of algorithm for aggregate segmentation

3.Results and discussion

Cement mortar can be regarded as a spatially homogeneous material. Aggregate particles are distributed in mortar as random nature. Based on the stereology principle, the area fractions of aggregate in images are equal to volume fractions of aggregate in each specimens $(A_A = V_V)$.

The original images and their binary segmentations for aggregate are shown in Fig.2. The average of area fractions of aggregate and their standard deviations are given in Table 1. In Fig.2, some aggregate particles, which have a similar color to the cement paste matrix at parts of edge line, were detected smaller than its real size after the operation of filling holes. However, as a whole, it can be seen that locations and shapes of the segmented aggregate were well represented in comparison to them of the original images. The average values for volume fraction of 5 and 10 images were close and the standard deviation values were small. Thus, it is found that aggregate segmentation by this algorithm was stable and only a few number of images was sufficiant for the analysis.

When small particles were connected to the bigger ones and their edge lines were not closed in non maxima suppression, aggregates were detected a little bigger compared with the original size. With C/S=1:1, C/S=1:2, the average area fraction of aggregate estimated from the images were close to the real values. However, in the mortar with C/S=1:3, it seem that those values were slightly different from the real value determined by the mix proportion. This may be partly due to increase of invisible aggregate particles, which were not detected in the image analysis.

On the other hand, the real values for volume fractions of aggregate in specimens here were calculated without regards of presence of air voids. However, some amounts of air voids were clearly seen in those mortars with the high sand content. In that case, the value of 54.2% may be overestimated. Therefore, taking account of such an error in the calculation, the method proposed in this study is concluded to give more reliable estimation for the volume content of aggregate.

4.Conclusions

By implementation of Canny edge detector, the outline boundary of aggregate was detected and aggregate phase was segmented precisely from an image of a cross section. Therefore, to obtain morphological information of aggregate and to estimate volume fraction of aggregate in mortars, the proposed algorithm is effective with requirement of a few of images.

5.Reference

[1] Yang, R. and Buenfeld, N. R., Cement and Concrete Research, Vol. 31, pp 437 – 441, 2001.

[2] Fang, C. and Labi, S., Transportation Research Board Annual Meeting, Paper #07-3339, 2007

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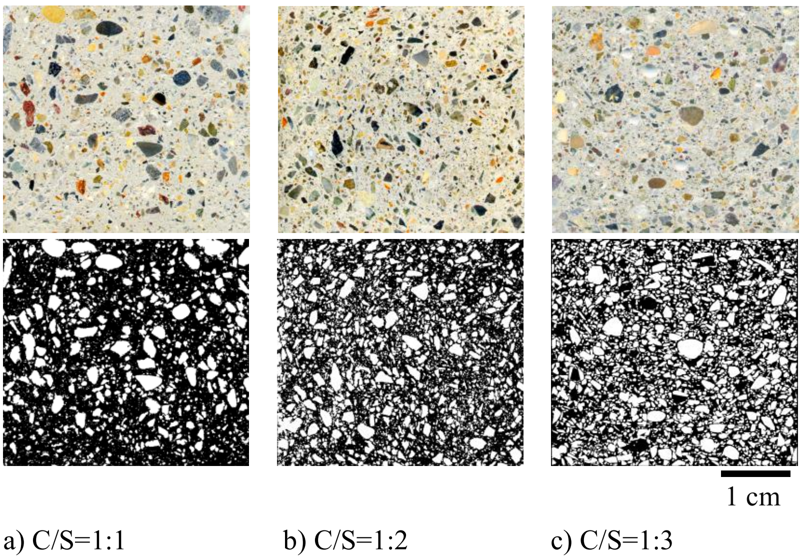

Fig.2 Original images and aggregate binary images

Table 1 Area fraction for each type of specimens (%)

Number of images	Area fraction	C:S=1:1	C:S=1:2	C:S=1:3
Real values		28.3	42.1	54.2
5	Average	29.4	43.2	51.3
	Std. Dev.	1.43	1.76	1.91
10	Average	29.6	43.5	50.6
	Std. Dev.	1.73	1.87	3.01