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EVALUATION OF AGGREGATES PARTICLE SIZE DISTRIBUTION IN LIGHTWEIGHT CONCRETE VIA IMAGE PROCESSING

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Abstract. The present work presents a means of evaluating the granulometry distribution of aggregates on hardened concretes via an image processing based technique. Such a technique may be employed to the reconstitution of hardened concrete composition, which is a matter of interest concerning, specially, expertise. The preliminary results of the study were obtained over synthetic images - and encourage further improvements in the employed algorithm in order to deal with actual concrete images.

1 INTRODUCTION

Aggregates particle size distribution - or gradation - is one of the most important characteristics regarding the utilization of aggregates in concrete (Dellarard and Belloe, 1999). Not only does it influence the material's mechanical properties but also durability aspects are affected.

Concerning lightweight aggregate concretes (LWC), the pre-defined aggregates gradation is not always present in the hardened material, due to the fact that the lightweight aggregates are commonly rather fragile and may be damaged during the mixing process (ACI, 2003).

The segregation phenomena due to lightweight aggregate low density may also locally change gradation distribution. During mixing, the vibration processes may cause some floatation of the lightweight aggregate (Ke et al., 2006; Kim et al., 2010).

In that way, specially for expertise, techniques to evaluate aggregates particle size distribution may help structural evaluation.

This work presents a means of evaluating gradation on hardened concrete samples via an image processing based technique. Such information may be employed to the reconstitution of this important aspect of a given concrete composition. The preliminary results presented herein were obtained from synthetic images, and encourage further improvements in the employed algorithm in order to deal with actual concrete images.

2 AGGREGATES GRADATION ANALYSIS VIA IMAGE PROCESSING

The aim of the proposed application is: starting up from a synthetic picture taken from a given hardened concrete plane section, to identify the aggregate particle size distribution in the mixture by means of image processing analysis based on classical thresholding and binarization procedures (Corr et al., 2007).

Assuming as valid the hypothesis that all the aggregate particles employed on a given concrete sample are spherical, any plane section taken from that sample will present only round aggregate sections with diameters depending on the cutting plane position. In that way, an aggregate particle of actual diameter D may appear on a given concrete plane section with a diameter $0 < d \leq D$.

This hypothesis is reasonable for some kinds of lightweight aggregates, as the one shown in figure 1.

Figure 1: Picture of a typical lightweight aggregate.

Now, let us consider two hypothetical aggregate particle size distributions presented in figure 2, referred as aggregate #1 and aggregate #2:

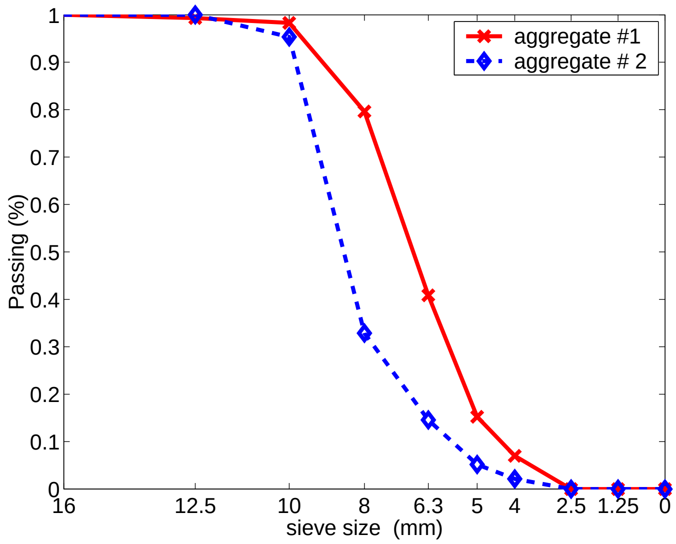

Figure 2: Two hypothetical aggregate particle size distributions used as reference.

By using each hypothetical aggregate particle size distribution it is possible to create synthetic section images as the one shown in figure 3 for illustration purposes.

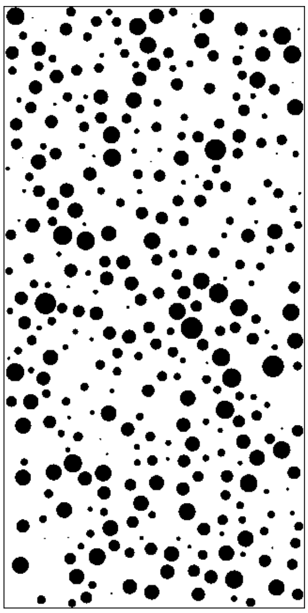

Figure 3: An example of the generated synthetic images.

Obviously, the diameter size distribution of the image (d) presented in figure 3 is different from the actual granumetric distribution (D) as shown in figure 4. In this figure a set of 20 d distributions obtained from 20 synthetic imagens randomly created for aggregate #1 is presented. Similar results may be achieve for aggregate #2. In this figure all synthetic images used in order to calculate d distribution have among 439 rocks.

A statistic representation of d distribution obtained for the set of synthetic images presented if figure 4 is shown in figure 5. Each point of this figure allows the dispersion evaluation of the results. Lower limit of the results, lower quartile, median, upper quartile values and upper limit are plotted. This kind of graphic representation is called by boxplot.

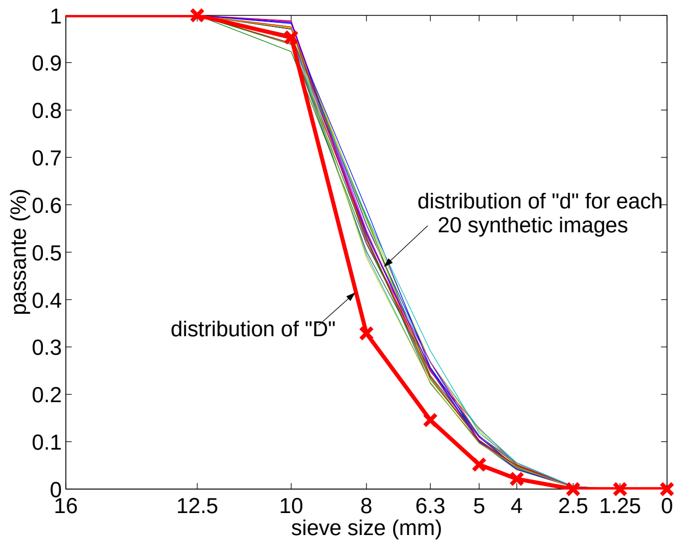

Figure 4: Comparison between actual diameter distribution D and image diameter distribution d.

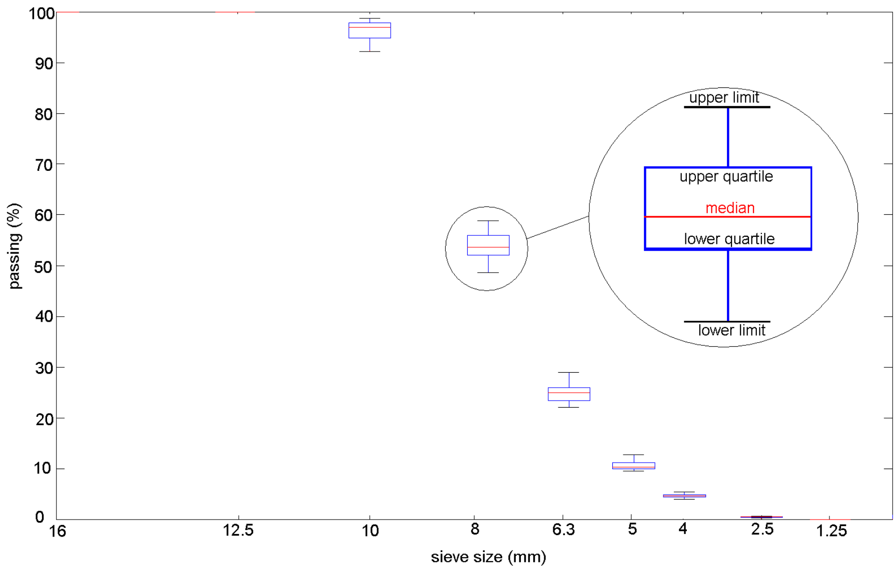

Figure 5: A statistic representation of d distribution using boxplot. 20 synthetic specimen cut images were used, having D distribution of aggregate #1 (see figure 2). All synthetic images comprise around 439 rocks

The distribution of d tends to be invariant as the amount of rocks in the section tends to infinity. Figures 6 and 7 present boxplots for aggregates #1 and #2, respectively. In these figures, horizontal axes represent the number of rocks in images and vertical axes inform boxplot results. Colors are used to add the identification of sieve size. As it is possible to verify in these figures, both analyzed aggregates present similar behaviour.

An important conclusion may be depicted from Figs. 6 and 7: The relationship between D distribution and d distribution tends to be unique as the number of sectioned rocks increases. In that way, using synthetic images with a significant number of sectioned rocks, one can obtain ϕ coeficientes of Eq. 1, where D_i is the actual passing quantity of aggregate in sieve size # i and d_i is the distribution obtained by image processing.

$$D_i = \phi_i d_i \tag{1}$$

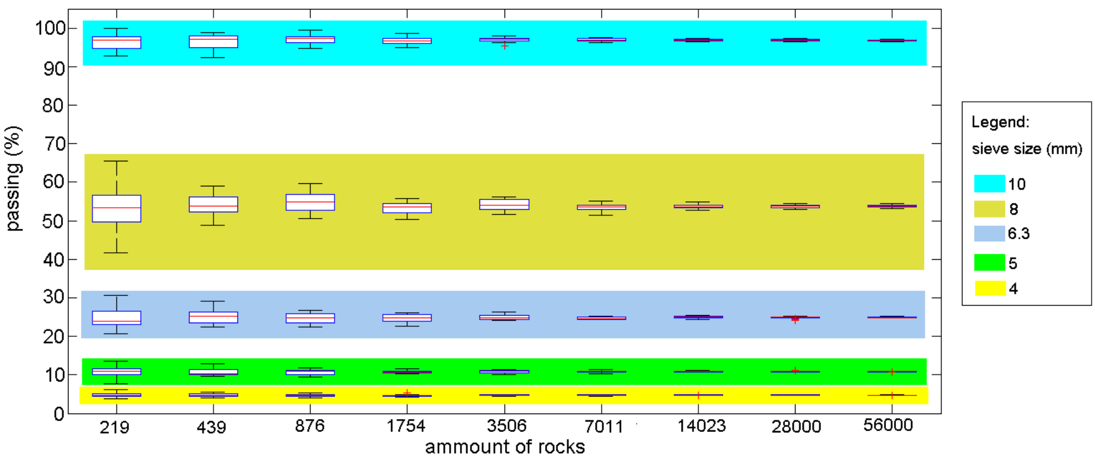

Figure 6: Boxplot of d distribution as a function of the amount of rocks in the used synthetic images - aggregate # 1

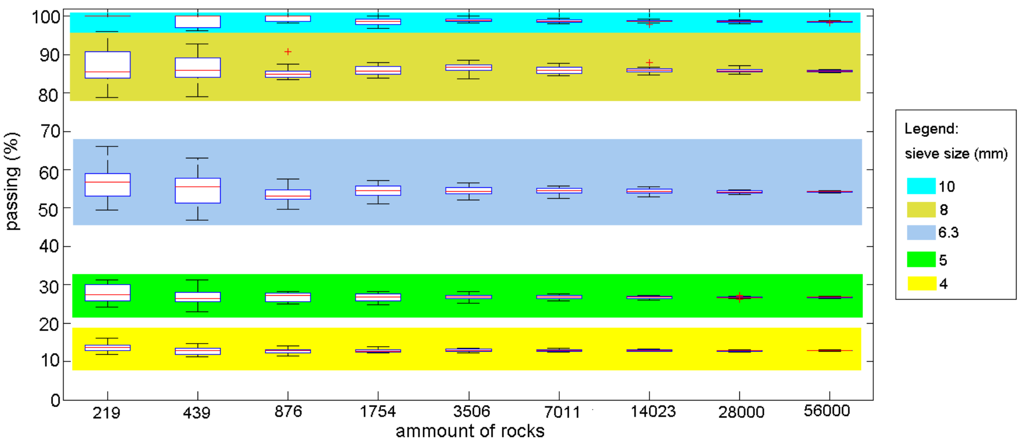

Figure 7: Boxplot of d distribution as a function of the amount of rocks in the used synthetic images - aggregate # 2

The next step of the proposed methodology is to create a database of aggregates with theirs respective ϕ coefficients. It may be carried out using synthetic images and both d distribution and ϕ coefficients are stored.

Finally, from a picture of a lightweight concrete (denoted by the superscript *) with an unknown actual D^* distribution, one determines its d^* distribution by using image processing. The closest result of d distribution in the database is linked to the unknown concrete and, by applying the respective stored ϕ coefficients, its actual D^* distribution may be achieved. The determination of the closest d distribution, Eq. 2 is applied:

$$\eta^j = \sum_{i=1}^{N} (d_i^* - d_i^j)^2 \tag{2}$$

where N is the number of sieves and the index $_j$ indicates the j-th d distribution in the database.

3 VALIDATION OF THE PROPOSED METHODOLOGY

In this paper it was employed a database of 120,558 granulometry distributions of D, which graphical representations are inside the assigned region of Fig. 8. The bottom and upper region limits are the granulometry distribution of aggregate #1 and #2, respectively.

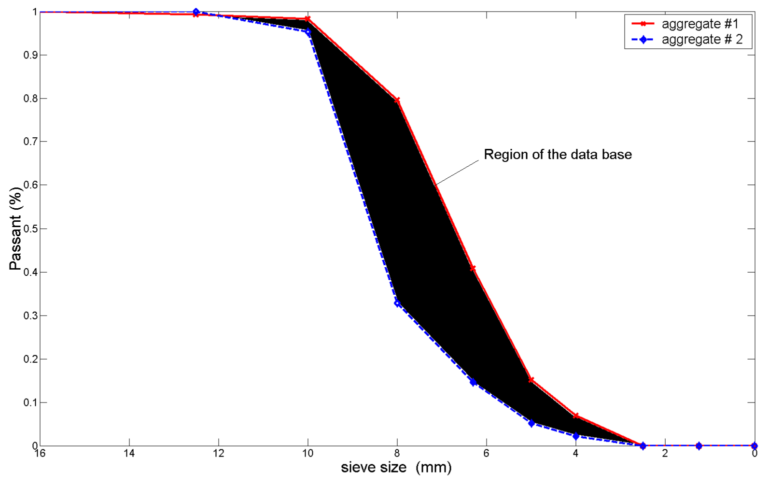

Figure 8: Region of the generated batabase

Two different lightweight concretes with different aggregates gradation are used in order to validate the proposed methodology. These concretes are denoted by “ aggregate a” and “aggregate b” and their gradations are presented in Fig. 9.

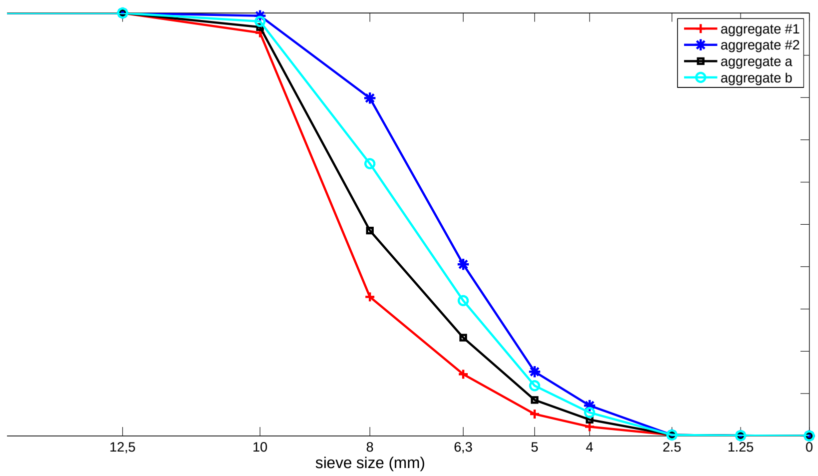

Figure 9: Granulometry distribution for the two concretes used for validation.

By considering concretes with aggregates “a” and “b”, synthetic images were generated, similarly to the one presented in Fig. 3, and, by using image processing, d^* distribution of each concrete is obtained.

Applying Eq. 2, the closest d distribution is determined and ϕ coefficients are applied in order to calculate actual D distribution for each concrete.

The proposed methodology was applied in three situations for each analyzed concrete:

Table 1: Passing percentage for aggregate a

sieve size (mm)	**16**	**12.5**	**10**	**8**	**6.3**	**5**	**4**	**2.5**	**1.25**	**0**
actual	100	100	96.7	48.5	23.2	8.5	3.8	0.2	0	0
situation #1	100	100	97.7	58.0	26.4	7.4	4.5	0.3	0.1	0
situation #2	100	100	95.8	45.7	23.6	8.4	4.0	0.3	0.1	0
situation #3	100	100	95.9	49.6	24.5	8.4	4.3	0.3	0.1	0

Table 2: Passing percentage for aggregate b

sieve size (mm)	**16**	**12.5**	**10**	**8**	**6.3**	**5**	**4**	**2.5**	**1.25**	**0**
actual	100	100	99.4	80.1	40.8	15.4	7.3	0.3	0	0
situation #1	100	100	99.8	84.3	41.3	15.3	7.1	0.3	0.1	0
situation #2	100	100	99.5	80.0	40.4	15.6	6.9	0.4	0.2	0
situation #3	100	100	99.5	80.3	40.2	15.6	6.8	0.3	0.2	0

- situation #1 - synthetic section image was generated with 876 rocks;
- situation #2 - synthetic section image was generated with 7011 rocks;
- situation #3 - synthetic section image was generated with 56000 rocks.

Table 2 and 2 summarize the obtained results. In both analysis cases actual aggregate distribution was fairly determinate. Obviously, for a increasing number of rocks in the synthetic images, the accuracy of the proposed methodology augments.

The preliminary results presented herein encourage the application of the proposed technique to images taken from actual concrete samples. To this end, an experimental program is now in progress at the Department of Civil Engineering of Cergy-Pointoise University (Laboratoire de Mécanique et Matériaux du Génie Civil) - where concrete samples presenting varying aggregates gradations will be prepared in order to allow further analysis.

4 CONCLUSIONS

A methodology for the evaluation of the granulometry distribution of aggregates on hardened concretes via an image processing based technique is presented in this paper. Preliminary results were obtained from synthetic images, and encourage further analysis on images taken from actual concrete samples made of spherical aggregates.

5 ACKNOWLEDGES

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