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Granulometry on Riprap Images

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Résumé. — L'étude de la stabilité des barrages en enrochements tient une place importante dans la maintenance des structures au Québec. Comme de tels barrages et digues s'étendent sur plusieurs dizaines de kilomètres, il est important de pouvoir réaliser une surveillance systématique de leur surface. C'est pourquoi, un processus d'acquisition et de traitement d'images a été mis en place afin de faciliter cette surveillance. Cet article explique comment les diamètres des blocs rocheux peuvent être déterminés sur les images pour tracer la courbe granulométrique.

Abstract. — Dam stability is of a matter of great importance in civil engineering, particularly in Quebec where dams and dykes are made in the same way. As such dams lie over tens of kilometers, it is very important to do a systematic survey of their surface. That is why a process of acquisition and image processing has been set up in order to make this survey easier. This paper presents how diameters of rocks can be computed from images in order to draw the granulometry curve.

1. Introduction

The establishment of a granulometry curve associated with a particle image is one of the applications of image analysis. For this kind of application, the main problem to solve is to identify each particle in order to measure its most interesting characteristics. For example, features measured on riprap images are diameters of stones. This application takes place in civil engineering. Computing the granulometry curve of a riprap enables the evaluation of the stability of an embankment dam to be completed. This paper presents on one hand how the three main diameters of stones are evaluated, and on the other hand, a comparison of the granulometry curve obtained by image processing to the experimental curves.

2. The Civil Engineering Context

A riprap is a set of big stones covering an embankment dam. Such a dam presents the structure of a filter, in other words, the core of the dam is made of the finest particles (clay), covered by a layer of sand, itself covered by a layer of small stones, itself covered by a layer of bigger stones and so on until reaching the outside, protected by the riprap. As a granulometry curve gives for each diameter the percentage of the total weight sieved by the equivalent siever, a variation of the curve to the left points out a degradation of the structure: so a degradation of the dam protection can be detected just by studying the granulometry curve. Experimental means have been set up to enable the elaboration of granulometry curves. Nowadays, the diameter measurement needs the estimation of an expert. Measurements are made manually and such a method is dull, lengthy and dangerous because technicians and engineers have to walk down often extremely slippery slopes.

Furthermore most of the rocks are not really reachable because they cover each other, that is why an expert must estimate the covered part of the rocks and the third diameter in depth direction, as stones cannot be moved. These measurements are made only at a few spots of the dam surface. When the three main diameters are measured for each stone of the considered spot, an estimation of the weight of stones is given by the following formula:

$$w = \tau \mu \bar{d}^3 \tag{1}$$

where: τ is the ratio between the stone volume and that of the minimal parallelepiped containing the stone, μ is the average volumic mass of stones, available for a given quarry, and $\bar{d}$ is the average diameter of the stone ($\bar{d} = \sqrt[3]{d_1 d_2 d_3}$).
(1) is then equivalent to:

$$w = \tau \mu d_1 d_2 d_3 \tag{2}$$

where: d_1 is the maximum diameter of the stone, d_2 is the sieving diameter of the stone, d_3 is the minimum diameter of the stone.

And we have the following property:

$$d_1 \geq d_2 \geq d_3. \tag{3}$$

Generally, $d_2 \cong d_3$. The granulometry curve is then drawn, giving for each average diameter value, the percentage of the total weight sieved for this value. A degradation of the riprap is pointed out by a variation of the curve as the weight of small elements increases. So, the dam needs to be repaired.

3. Image Acquisition

A video band of riprap surface is acquired by a camera hung at the end of a boom mounted on a truck (see Fig. 1). This truck moves along the top of the dam. The video band is then cut up into a set of adjacent images. A riprap image (see Fig. 2) shows a square spot of the dam surface and gives a contrast value at each point. Rocks do not fit perfectly together so, they are separated by voids. These voids appear darker than rocks on the image because they are in shadowed areas.

4. Diameter Measurements by Image Processing

4.1 SIEVING DIAMETER. — The sieving diameter is the easiest diameter to measure. The grey-level image is thresholded and stone boundaries (found by gradient computation) are added to the thresholded image [1] in order to get the binary particle map. Then particles are partially

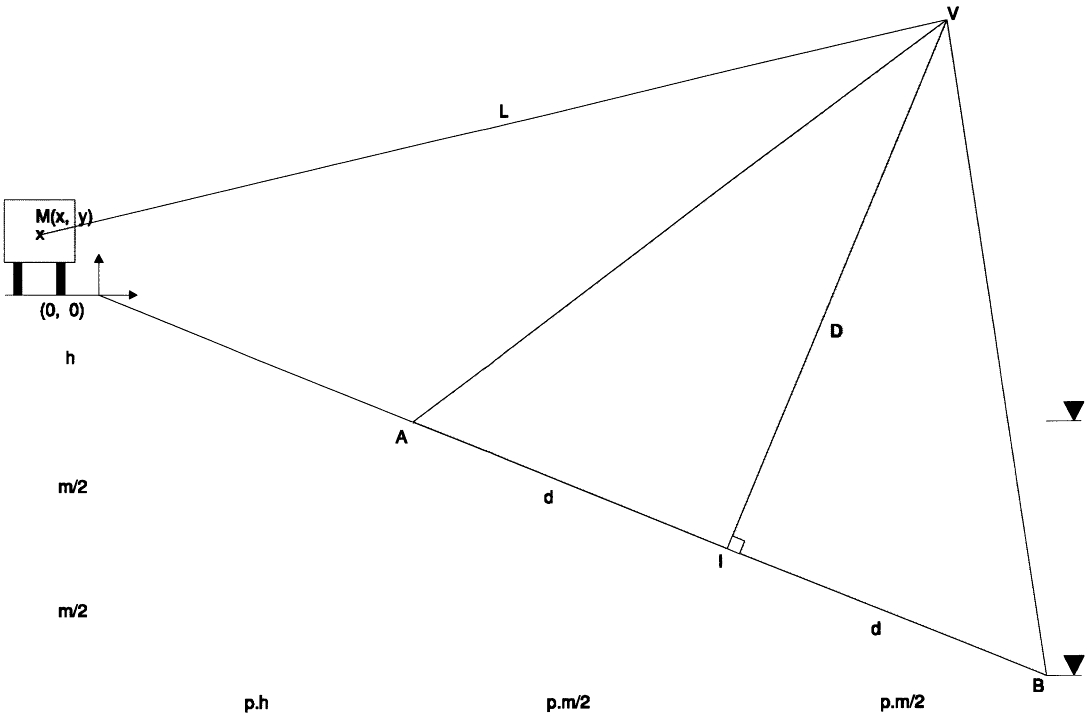

Fig. 1. — Image acquisition. The video camera V acquires a band of the riprap surface.

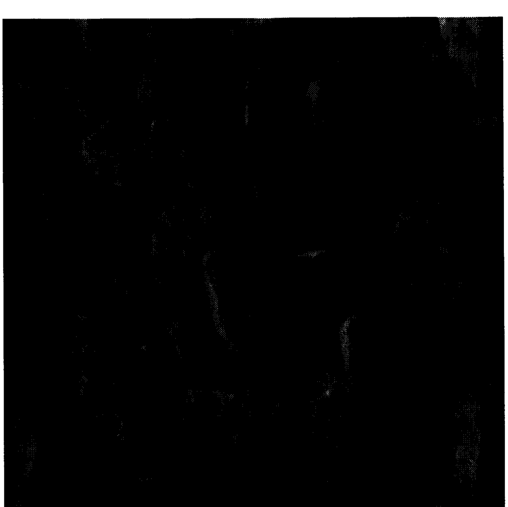

Fig. 2.

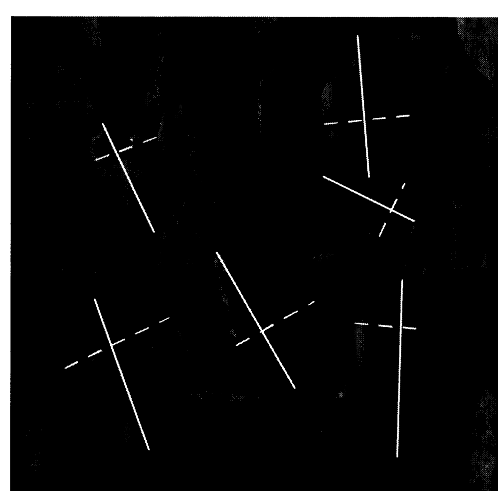

Fig. 3.

Fig. 2. — Riprap image.

Fig. 3. — The two main diameters are measured on the riprap image.

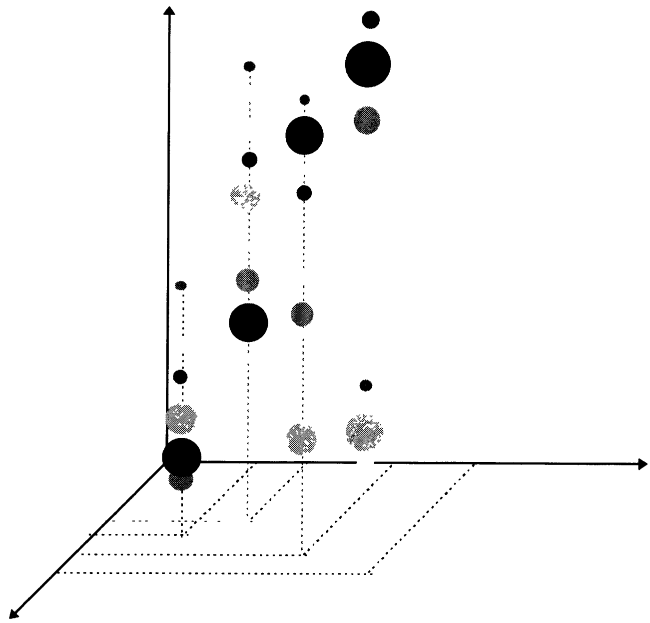

Fig. 4. — Statistical evaluation of d_3.

disconnected and a distance map is computed from this particle map. This distance map gives for each point belonging to the stones its distance to the voids. Then a detection of local maxima on this map enables the sieving diameter to be evaluated, as the distance value is equivalent to the radius of the inscribed disk and this radius is assumed to be equivalent to the sieving radius [2].

4.2 MAXIMUM DIAMETER. — The partial disconnection of particles processed at the previous step is not sufficient to enable to evaluate the maximum diameter. Actually, it is necessary to compute a full disconnected particle map in order to be able to evaluate the maximum Féret diameter [3]. When each particle is identified (fully disconnected from the others), Féret diameters are computed for a set of directions [4]. The finer the sampling of direction is, the more accurate the maximum diameter evaluation is (see Fig. 3).

4.3 ESTIMATION OF THE THIRD DIAMETER. — This diameter value is not reachable by image processing as the riprap image is only a bidimensionnal image and gives contrast information. A statistical evaluation has been set up, based on experimental data (see Fig. 4). As manual experiments have been done on the riprap, diameter values are available in the three dimensions. Experience has proved that most of the rocks are placed in the riprap in such a way as to make the two greatest diameters apparent. Beyond this assumption and according to (3), a random function can be described giving for each pair of values (d_1, d_2) a statistical estimation of d_3.

5. Granulometry Curve by Image Processing

Information about the three main diameters has been extracted from the riprap image. The weighted size of each stone can then be computed according to (2). And the granulometry curve

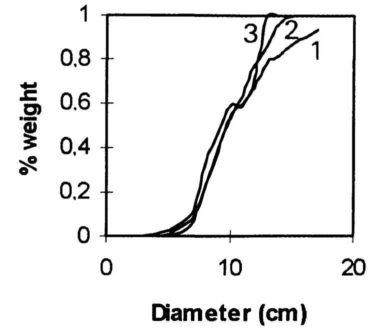

Fig. 5. — Granulometry curve associated with a riprap image. (1) Summed weight (d_2). (2) Summed weight (average diameter). (3) Summed weight (image processing).

by image processing is obtained by summing up, for each $\bar{d}$, the weighted size of stones whose average diameter is less than $\bar{d}$.

Figure 5 shows a graph on which the image processing curve and the experimental curve can be compared. One can notice that the two curves are very close to each other in the neighborhood of 50%. The corresponding diameter value d_{50} is very interesting from the point of view of civil engineering because it is an important parameter for the estimation of the structure stability [2, 5]. Greater differences can be pointed out for the smallest and the biggest $\bar{d}$ values because of errors due to image processing. For these particular values, most of them are detected because of noise from boundary detection, smallest values being due to contrast variation residue and biggest values to boundaries not detected because of a lack of contrast.

6. Conclusion

Granulometry estimation by image processing is very interesting for dam stability evaluation because the user does not need a particular knowledge in image processing, as the whole process can be automatic. Furthermore it does not require manual experiments on the dam itself. Actually, experimental data for the third diameter estimation can be obtained in the quarry from which rocks have been extracted. There, rocks are not on dangerous slopes and the three diameters can be measured more accurately. Another advantage of this method is that the process can be completed for the whole riprap surface. It only necessitates acquiring a video band of the riprap surface and then, the computation can be processed afterwards.

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