



OPTICAL INSPECTION OF CONCRETE SURFACE

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Abstract

In order to obtain accurate and reliable data on the properties of concrete surfaces, professional testing methods and specialised equipment may be required. Optical inspection can be carried out as part of, or as preparation for, diagnostic testing. This paper describes a procedure that can be applied to microscopic inspection too, as it is based on data obtained from the use of a software package developed for biological digital image processing. As an example, the quantification of cavities on the side of a concrete cube specimen is described, step-by-step, but such a convenient procedure could also be used to evaluate other surface features.

Keywords: concrete, surface, inspection, digital image processing.

1. Introduction

Concrete is one of the most widely used materials in the construction industry because it is easy and cost-effective to produce. Fresh concrete is malleable, so it can take almost any shape, and once hardened it is resistant to compressive loads and has a long service life. Its quality depends mainly on the raw materials (cement, water, aggregates, mineral and chemical admixtures), the appropriateness of the construction technology and maintenance. The strength and durability of concrete are influenced not only by the type of aggregate and cement, but also by the porosity (pore size and pore distribution) of the cement paste formed after the cement slurry has set [1]. The porosity of hardened concrete is important not only for strength and durability, but also for frost resistance, water resistance and surface wear, in addition to aesthetic requirements. The type of cement should be selected according to the environmental conditions, taking care to respect an appropriate water-cement ratio [2].

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2. Concrete surface appearance

During the optical inspection of concrete surfaces, the following features can usually be assessed:

- colour;
- evenness;
- texture;
- wear;
- cracks;
- possible contaminations;
- temperature;
- moisture;
- porosity.

The colour and appearance of the concrete surface can be important from an architectural (aesthetic and functional) point of view. Surface evenness is an indicator of the quality of the finish, smoothness, roughness, and possible irregularities are important especially for traffic surfaces and for pavements where texture also plays a role.

The extents of surface wear and tear, erosion or other forms of surface damage are relevant in determining the need for maintenance or repair. The presence, size and extent of cracks on the concrete surface can be a key factor in assessing the structural integrity and durability of the concrete. Also indicative of durability is the degree of surface creep or shrinkage.

From the point of view of maintenance and cleaning, it is important to assess the presence of any contaminant, efflorescence or biological growth on the concrete surface. Measuring the temperature of the concrete surface can be useful for evaluating the curing and hardening process, identifying possible thermal stresses or optimizing energy efficiency in a temperature-controlled environment. While the amount of moisture present on the concrete surface can help to assess the curing process, it can also help to identify potential problems such as water leaks. Surface porosity data helps to evaluate the permeability of the concrete surface, which is essential in assessing the durability and resistance of the concrete surface to moisture or chemical penetration.

In order to obtain accurate and reliable data on the above-mentioned features of concrete surfaces, professional testing methods and special equipment may be required.

Optical inspections can be part of, or preparation for, diagnostic examinations. Although the range of such inspections is quite wide (e.g. photogrammetry, stereoscopy, surface scanning, transillumination, radiation examination, etc.), in this paper we describe only one method based on digital image processing derived from microscopic inspection.

3. Digital imaging

3.1. Basics

Only optically detectable and measurable features can be evaluated by optical inspection. The optical inspection refers to visual examination and the use of optical instruments. Ocular assessment often provides inaccurate or insufficient data, so it is recommended that it be supplemented by the use of appropriate optical instruments. Although analogue instruments are accurate, the data obtained with them can be more difficult to handle than numerical data. By using digital tools, it is easier to expand and enhance data management, for example by filtering noise and disturbances, making geometric or morphologi-

cal image transformations, image segmentation, etc.

A digital photograph is a set of elementary points (pixels), usually with colour intensity values between 0 and 255. More values are required for each pixel in the case of colour images (3 values for RGB components of displays, 4 values for CYMK components of printers), while 1 value is required for grayscale images. For black and white images, there are no colour intensity values because one bit is sufficient to characterise a pixel. Digital image processing is a form of signal processing in which algorithms are used to process the data set that makes up an image.

The distribution of intensity values of colours or greyscales can be displayed using a histogram. If this can be modified, the display can also be changed by thresholding the intensity of the pixels.

3.2. Procedure

During our inspection, in addition to visual examination, we took photographs of various concrete surfaces with a digital camera and then processed the recorded images with software in order to obtain easily interpretable numerical results.

As we wanted to involve civil engineering students in our research, we looked for digital image processing software that did not require any knowledge of programming languages. For digital image processing, we first used *Irfanview* [5] which allows us to easily check the image quality and crop the image of the surface under investigation. The resulting cropped digital image was analysed using the software package *Fiji* [6, 7] which allows, among other things, the evaluation of the characteristics of the different spots (particles). In principle, the following steps were applied:

- thresholding the colour intensity values of the opened digital image;
- mask creation for the displayed image;
- setting the analysis options;
- performing the analysis.

The numerical values (pixel sizes, minimum and maximum colour intensity values, averages, deviations, etc.) were obtained in two text tables (CSV files) according to the software's analysis option settings. The pixel sizes obtained had, of course, to be converted proportionally into real surface areas, based on the overall pixel number of the digital image analysed.

It is important to note that the quality of the opened image and the trimming of the colour intensity threshold (which strongly influences the generation of the mask) have a decisive influence on the quantity and accuracy of the numerical results. A more detailed description of the procedure is given in the following example.

3.3. Example of use

During practical laboratory work, civil engineering students cast concrete cube test specimens and then subjected them to a compressive strength test.

We photographed the side view of one such cube test specimen made of C20/25 concrete, after the surface appeared suitable in terms of colour and texture. Since each edge of the cube is 150 mm long, the cropped digital image section showing only the side face was resized to 1500×1500 pixels to simplify the calculations (Fig. 1). The aim of the examination was to quantify the cavities on this face of the cube.

After opening the cropped and resized image, it was converted to 8-bit greyscale in Fiji, and then the thresholding of the intensities was changed by trimming in the histogram (Fig. 2). Setting the proper threshold is critical to the image detail that will be displayed.

The program's measurement inputs allow the selection not only of the surfaces of the spots (particles), but also their perimeters, greyness and many other characteristics, but in this case we limited ourselves to the number and size of the cavities. After thresholding, we generated a black and white mask and selected to show a drawing of the numbered outlines for evaluation (Fig. 3). The details of the automatically generated mask depend on the level of thresholding, lower values resulting in fewer spots and reduced patch areas, while with higher values more and smaller noise, also larger patch areas will be displayed.

Due to the fragmented edges of the concrete cube, the spots (so called particles) on the edge-

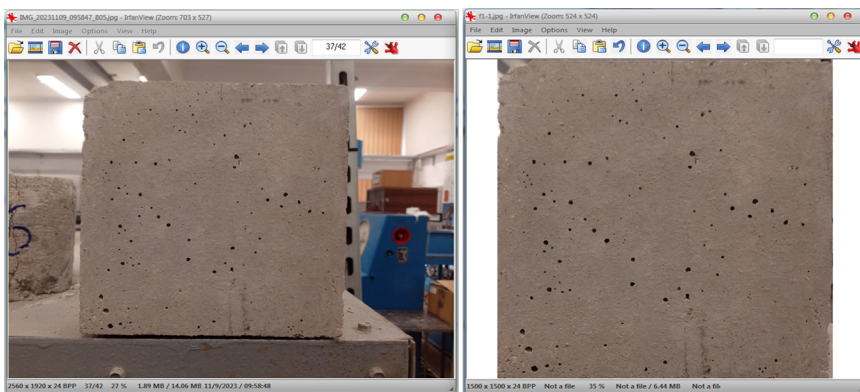


Fig. 1. Laboratory photograph of the concrete cube test specimen (left) and a cropped, resized image of the face (right).

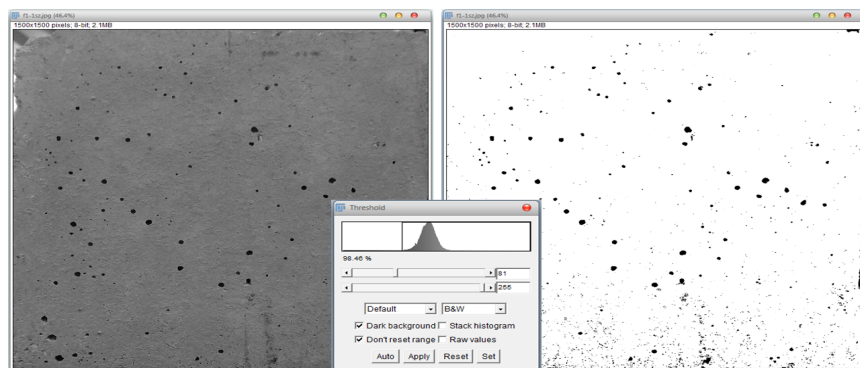


Fig. 2. Greyscale image (left), the histogram (centre) and the resulting image after the threshold (right).

es of the mask were ignored. In addition to the numbered contour layout drawing, the program provided the pixel measurement results in two tables: a “Summary” table and a detailed “Results” table (both as text files with comma-separated values), as displayed in Fig. 4. The detailed „Results” table contains the numbering of the contours and their areas measured in pixels.

3.4. Numerical results

From the pixel measurement results obtained, the actual size of the spots can then be calculated, knowing that a 1500×1500 pixel image corresponds to a 150×150 cm face (i.e. 1 pixel = 0.1 mm × 0.1 mm, or 0.01 mm²). From the detailed measurement table, it is then possible to calculate the size of each marked spot, as well as statistical characteristics for the spots detected (it being also possible to filter or group by size).

After reprocessing the data obtained from the image processing, the total area of the cavities is 3.1538 cm², which represents 1.40% of the 225 cm² concrete side area.

Of course, the data from image processing also depends on the parameters set for the analysis, not just on the quality of the digital image being processed. With the setting shown on the right in Fig. 3 (1.2–Infinity pixels²), 1983 spots (so called particles) were detected, but with the default settings of the program (0–Infinity pixels²), 2869 spots would have been detected. If the default settings had been used, the total area of the 2869 spots would have been 32424 pixels, or 3.2424 cm², which is 1.44% of the 225 cm² face area.

In the saved detailed “Results” text file, the data can then be filtered by pixel spot size to see the effect of the particle size setting of the analysis.

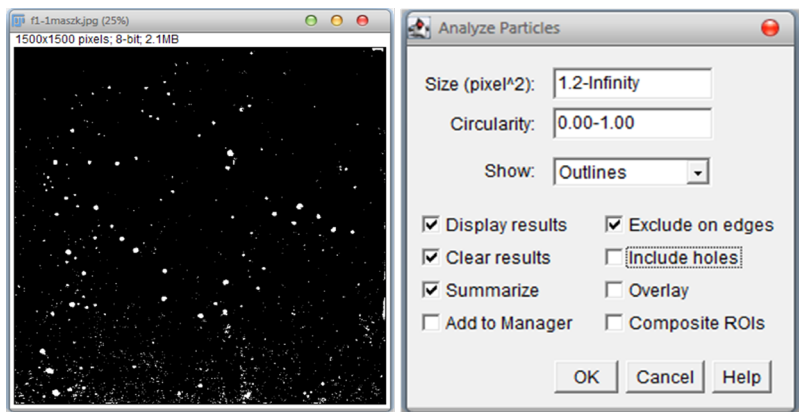


Fig. 3. The created mask (left) and the particle analysis settings window (right).

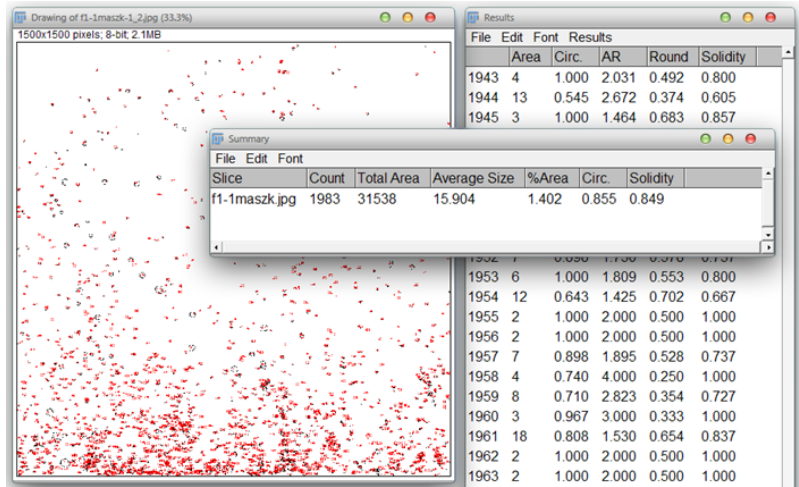


Fig. 4. The drawing of the numbered outlines and the results that are offered in 2 tables.

In [Table 1.](#) and [2.](#) in the first column “m” is the minimum pixel size considered, the second column shows the number of spots larger than the minimum pixel size, the third and fourth columns show the summarised area (in pixels and cm² respectively) corresponding to the number of spots, and the last column shows the percentage value relative to the 225 cm² area of the concrete cube’s face.

Table 1. *The values obtained with the default setting (0-Infinity pixel²).*

m	Spots	Area		
		[pixel]	[cm ²]	[%]
0	2869	32 424	3.2424	1.44
1	1983	31 538	3.1538	1.40
2	1484	30 540	3.054	1.36
3	1206	29 699	2.9699	1.32
4	997	28 863	2.8863	1.28
5	822	27 00	2.79	1.24

Table 2. *The values obtained with the example setting (1.2-Infinity pixel²).*

m	Spots	Area		
		[pixel]	[cm ²]	[%]
0	1983	31 538	3.1538	1.40
1	1983	31 538	3.1538	1.40
2	1484	30 540	3.054	1.36
3	1206	29 699	2.9699	1.32
4	997	28 863	2.8863	1.28
5	822	27 900	2.79	1.24

It is easy to observe the identical values in the first two rows of [Table 2](#), indicating that in this case no 1 pixel spots were detected by the analysis. The parameter used in the example shown has effectively filtered out the 1 pixel dots , so the same number of spots and areas are seen in both tables from the second row down.

Resizing the initial cropped image of the side of the concrete cube to 1500×1500 pixels is unlikely to have negatively affected the results, as it was originally larger.

4. Conclusions

A sensitivity test can also be carried out in order to ensure that the results are the right ones. In many cases, one of the goals in digital image processing is to reduce the amount of data. The less data to work with, the faster and easier the process.

Finally, the question may arise: which results are correct, which parameters should be used? Depending on the task at hand, the correct answer to this question can only be given on the basis of the expertise and experience of the person applying the procedure.

The technical tool used for the presented optical inspection is based on digital image processing. Although the software package used in this research was designed for biological digital imaging, this does not limit its application in other fields. The digitisation of the optical inspection and the use of computational tools offer many advantages and the handling of numerical data offers many possibilities, but it should not be overlooked that the results are generated from the input data.

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