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# Estimation of the structure of air entrained concrete using a flatbed scanner

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**Abstract**

This paper describes the possibilities of estimating the structure of concrete with the help of automatic image analysis using a high-resolution flatbed scanner. Sample preparation techniques and components of the image analysis system are described. Concerning the structure of the entrained air voids system, it was found that the results obtained using a high-resolution flatbed scanner were comparable to those obtained by conventional methods, i.e. using a system equipped with stereomicroscope. The possibility of automatically measuring the paste content in hardened concrete by analysis of plane sections, taking into account information available in RGB histograms, is also presented. A new procedure is proposed for the identification of the distance from the cement paste to periphery of the nearest air void, which enables rapid evaluation of the quality of the air entrainment treatment The procedure also allows some characterization of the aggregate component.


*Keywords:* Image analysis B; Concrete E; Cement paste D; Air voids

## 1. Introduction

The existence of a relationship between various structural parameters and properties of a material is one of the basic paradigms in materials science. Quantitative evaluation of the structure enables valuable conclusions to be drawn about the quality, mechanical properties or durability of the material. The aim of the investigations presented in this paper was to establish procedures for appropriate sample preparation and automatic, quantitative estimation of the structure of hardened concrete; in particular of air-entrained concrete. Such estimation is important from the point of view of frost resistance and durability.

It is generally accepted that the air voids structure is a critical parameter of concrete freeze–thaw resistance, at least in the case of a normal strength concrete, (less obvious in case of HPC). The traditional way of determining the air void characteristics of concrete is by microscopic examination as described in standards ASTM C 457 or EN 480-11 [1,2]. As a tool for the estimation the automatic methods of image analysis have become common. The most common source of images for investigation of the quality of air-entrained concrete is a video camera coupled with a microscope. The use of a flatbed scanner in the estimation of air-void characteristics was tried previously without success due to limited resolution of the scanner, [3]. The appearance of new, inexpensive, high-resolution scanners has made possible their application with sufficient accuracy.

The automatic procedures of image analysis systems applied in estimation of the air void parameters are rapid and precise, however, these procedures do not measure the cement paste content of the analyzed surface. According to the model of Powers, referred to in the standards, the paste content is an important parameter required to obtain accurate characteristics of the air void structure and it must be provided by the operator. This paper demonstrates the possibility of high accuracy evaluation of the air voids system using a flatbed scanner with simultaneous measurement of the quantity of cement paste. Additionally the

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procedure makes possible certain quantitative evaluation of aggregates arrangement.

## 2. Description of equipment

Two different systems were compared at the IFTR PAS laboratory for the tests described in the paper. One was composed of image analysis software, and software to control the scanning table, an automatic scanning table, a stereoscopic microscope, a color video camera and a cold light source—"swan neck". The second system was the same image analysis software and a flatbed scanner.

In the first (microscope based) solution the specimen is placed atop the scanning table, which can move along $X$ and $Y$ axes up to 150 mm, with accuracy of 0.1 μm. Magnification of the stereoscopic microscope is between 10× and 63×. Color video camera has three CCD matrices, one matrix for each component of an image in the RGB system. With help of the applied video camera it is possible to capture 24 bits color images at a resolution $768 \times 576$ pixels, in a rectangular net, or 8 bits grayscale images at the same resolution. To determine the air-void characteristics the magnification was typically 30×, so that a single pixel in the image corresponded to 2.76 μm on the surface of the specimen.

In the second (flatbed scanner based) solution the specimen is placed on the glass top of a flatbed scanner. The scanner used in the tests had an optical resolution of 2400 ppi (points per inch), which means that the smallest point of the image–one pixel–corresponds to 10.6 μm on the specimen. Images obtained from the scanner are recorded in the same 24 bits RGB as in case of the video camera described previously.

Algorithms for measuring the structural parameters have been prepared using the programming language built-in in the image analysis software [4], which makes possible application of morphological filters and various complex image processing operations.

## 3. Sample preparation technique

The technique of specimen preparation for estimation of the air void parameters in concrete was first developed at DBT Laboratory (Dansk Beton Technik), in Hellerup, where it has been successfully applied for a long time, and it was later modified at the IFTR PAS Laboratory in Warsaw. Concrete specimens of planar dimensions $100 \times 100$ mm are prepared by cutting, grinding and finally polishing (with help of SiC polishing powders). To avoid defects in observation area the polished surface is inspected with help of a stereomicroscope and proper assessment of the quality demands really experienced operator. The polishing is continued until the surface is free from defects. The next step is coloring of the surface with help of a blue, water resistant marker, which is followed by filling the air voids with zinc paste. Surplus paste is removed using a sharp blade: the surface is cleaned and finally protected using paraffin oil. At the end, the quality of preparation, and especially the accuracy of the air-void filling by the zinc paste is controlled under the microscope. If the quality of the surface is inadequate the whole process must be repeated, as this is one of the most important elements of the preparation. Description of possible defects in the polished surface was given for example by Pleau et al. [5].

The above description concerns the preparation of specimens for microscopic observations. There are certain differences in the sample preparation technique used for estimation of the structural parameters with help of a flatbed scanner. For separation of cement paste regions from the image of the whole concrete sample a special treatment has been worked out at the IFTR PAS laboratory. After the polishing concrete samples are shortly soaked in a blue ink (not painted by a blue marker as in the first solution), which results in cement paste area dyed blue, with the color of a typical aggregate almost unchanged. After dyeing the air voids are filled with white zinc paste as in the first solution. In

Table 1
Comparison of results of measurements of air void parameters obtained using a flatbed scanner and a stereoscopic microscope

| No. | Parameters obtained with help of microscope | | | | Parameters obtained with help of scanner | | | |
|---|---|---|---|---|---|---|---|---|
| | $\overline{L}$ (mm) | $\alpha$ (mm$^{-1}$) | A (%) | $A_{300}$ (%) | $\overline{L}$ (mm) | $\alpha$ (mm$^{-1}$) | A (%) | $A_{300}$ (%) |
| 1 | 0.17 | 32 | 4.43 | 1.72 | 0.15 | 31 | 5.40 | 2.79 |
| 2 | 0.19 | 26 | 4.54 | 1.51 | 0.17 | 28 | 5.28 | 2.51 |
| 3 | 0.19 | 30 | 4.07 | 1.79 | 0.17 | 32 | 4.76 | 2.62 |
| 4 | 0.12 | 33 | 5.94 | 2.58 | 0.11 | 33 | 6.25 | 3.99 |
| 5 | 0.16 | 30 | 4.16 | 1.92 | 0.17 | 27 | 4.80 | 2.60 |
| 6 | 0.12 | 40 | 4.94 | 2.55 | 0.13 | 36 | 4.78 | 2.92 |
| 7 | 0.09 | 31 | 7.51 | 3.09 | 0.12 | 27 | 6.31 | 3.22 |
| 8 | 0.12 | 28 | 6.99 | 2.81 | 0.16 | 26 | 5.81 | 2.83 |
| 9 | 0.15 | 47 | 2.41 | 1.05 | 0.17 | 42 | 2.10 | 1.44 |
| 10 | 0.28 | 17 | 5.14 | 0.86 | 0.28 | 18 | 4.68 | 1.12 |
| 11 | 0.14 | 10 | 14.68 | 1.03 | 0.14 | 11 | 14.35 | 1.49 |
| 12 | 0.14 | 28 | 6.82 | 1.83 | 0.13 | 27 | 7.43 | 2.90 |