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METHOD OF MEASURING LATERAL DEFORMATION OF SOLIDIFYING CONCRETE UNDER UNIAXIAL LOADING

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Summary: *The measurement of lateral deformation of solidifying concrete founds its application in many concrete technology fields. In this article, we present a method of using a CCD camera to measure the lateral deformation of solidifying concrete under uniaxial loading. The proposed method is based on processing of high-resolution images for data acquisition.*

1. Introduction

At present, there is no special testing method for measuring the lateral deformation of solidifying concrete. Contact methods, which are used for hardened concrete are unsuitable for solidifying concrete due to either incapability of attaching measuring apparatus to the surface or the lack of adhesion in case of embedded strain gauges. The use of a laser sensor also is not easy to be applied since the longitudinal deformation of solidifying concrete is rather large, which requires some mobile attachment of the laser sensor so that it can follow the targeted spot with progressing longitudinal deformation. An optical method where the image is captured with a high resolution CCD camera is relatively easy and nowadays also inexpensive. Capturing an image solves the part of acquiring test data on lateral deformation, however, conversion of the image data to lateral deformation measurement requires some intention.

In this paper, we propose a method using a high-resolution CCD camera to measure the lateral deformation of solidifying concrete under uniaxial loading. The objective of the work is to measure the specimen's width under uniaxial loading. The method was used at the ages after the initial setting time when it was possible to demold a concrete specimen.

2. Testing method

A CCD camera (3040x2016 pixels) was used. In order to distinguish the edges of the specimen from the background, a dark curtain was installed behind the test set and the specimen was illuminated on both sides with two spotlights, Fig 1. The focus of the camera was set in advance and kept constant. The shutter of the camera was correlated in terms of

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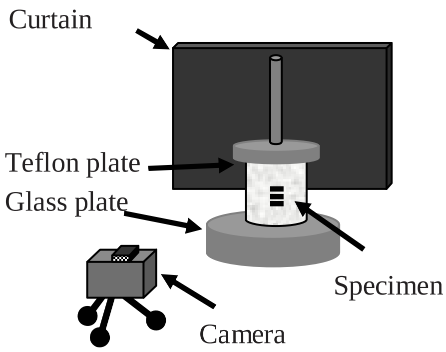

Fig. 1 Test configuration

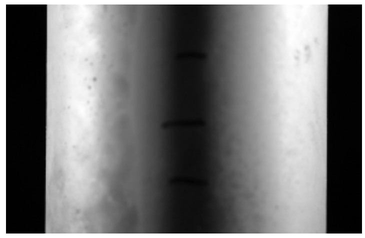

Fig.2 Captured image of specimen

time with a PC collecting data on longitudinal displacement (LVDT, stroke 200mm) and loading force (loadcell). The loading force was imposed by an electric actuator with an online fuzzy controller. An example of a captured image is shown in Fig 2.

3. Images processing

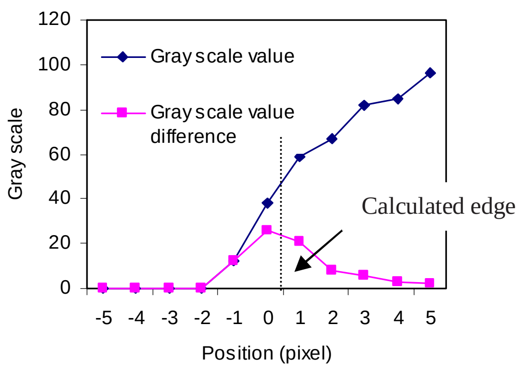

Fig.3 Digitized edge of specimen

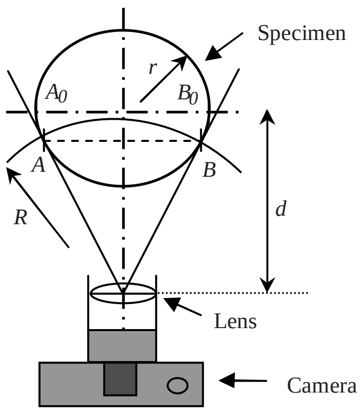

Fig. 4 Correction of measurement

Three stripes were cut from a captured image. The monochromatic bitmap image comprising data in the form of 256 grades of gray scale was converted to an array of digits for each pixel. In order to detect the edges of the specimen, on the subpixel domain, the center of the gravity of the area under the curve defined by gray scale value differences of neighboring pixels, Fig 3, was calculated.

The distance between the centers of gravity on both sides of the specimen defines the width of a specimen, A_0-B_0 in Fig 5. However, because the distance of the camera from a specimen is of about the same order as the width of the specimen, some correction of the reading, *A*-*B* in Fig 5, should be introduced. From elementary geometry applied to the problem shown in Fig 5, where *r* is the radius of a specimen and *d* is the distance between the lenses of camera and the center of a specimen, the correction factor c can be derived as

$$c = r\left(\cos\left(\arcsin\frac{r}{d}\right) - 1\right) \qquad (1)$$

The image processing can be described by the flowchart of the computer program:

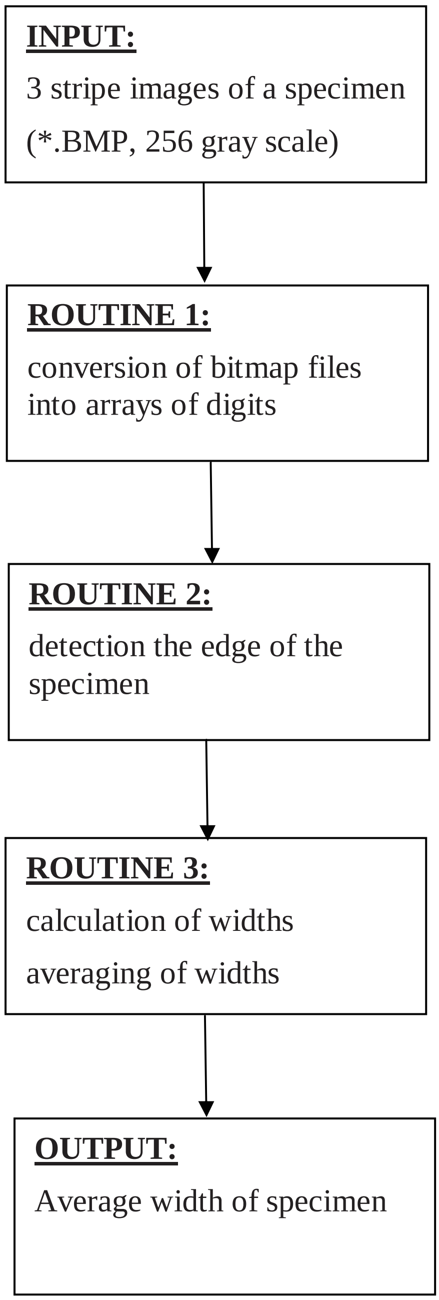

Fig.5 Flowchart of processing

INPUT:

In order to minimize the effect of a local damage, the input batch consisted of three stripes cut out of the overall height of a specimen.

Routine 1:

The conversion of a bitmap into an array of digits can be achieved by a selection of a proper function available in a programming language. The commonly used languages which are designed primarily for numerical calculations, such as the Fortran family, can import the graphics functions from other languages, such as C++, or even more easily from Matlab or Mathematica.

Routine 2:

The file obtained from the conversion of a rectangular image is usually in the format: the number of pixels in a row or a column, the values of pixels written row by row or column by column. For the edge detection it is necessary to exclude the effect of inhomogeneities caused, e.g. by holes on the surface of the specimen caused by air bubbles, which may delude the edge detecting routine. For this reason it is desirable to allow a height of a stripe of at least twice the size of the largest inhomogeneity near an edge. After averaging the pixel values in each column, a vector with the number of entries equal to the number of the column is obtained, in which 0 means black and 255 means white. Because the edge actually means the greatest difference between the colors of specimen and the curtain, the vector is converted to a vector of the differences between neighboring pixels. The center of gravity should be calculated for an area which is limited by the length of 3-7 pixels near the initially localized edge on both sides of the pixel with the greatest value.

Routine 3:

The width of a specimen is calculated as the difference between the real number indicating the position of the entries in the vector of the differences which defines the edge on both sides of a specimen. The conversion into a real width is conducted with respect to the mm/pixel ratio. However, for the investigation of the Poisson's ratio, the conversion is not necessary since only the changes of the width corresponding with various load levels or various times are of interest.

Output:

The output of the program consists of three widths calculated for the three respective stripes, and the average width of the specimen.

4. Experiment data

The experiment was conducted with specimens (ϕ 100mm and height 200mm) for two types of mixes using rapid hardening Portland cement (RHPC). The mix design is summarized in Table 1. The Poisson's ratios, as a function of a load level for respective mixes are shown in Figs. 6 and 7. Due to inconsistent reading of both the longitudinal and lateral deformations related to settling of the specimen at the beginning of loading, the reading of Poisson's ratios before the load level of about 20% were excluded.

Table 1 Mix proportions

Type	Weight per unit volume (kg/m^3)			
	W	C	S	A
Type 1	168	271	767	1136
Type 2	181	490	598.5	1093

Target 28day strength = 30MPa (Type 1)
(Type 2)

Target slump = 8cm
Target air content = 2%

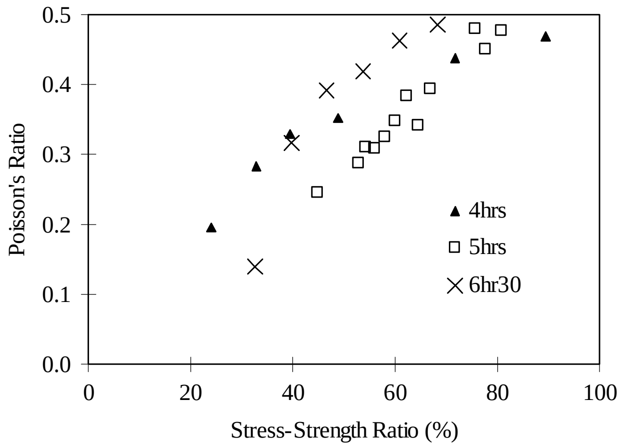

Fig.6 Poisson's ratio (Type 1)

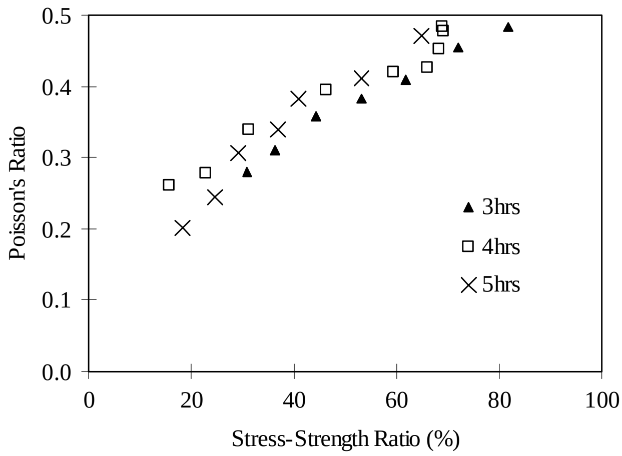

Fig.7 Poisson's ratio (Type 2)

5. Conclusions

A testing method is developed here using high-resolution CCD camera for measuring time-dependent lateral deformation of solidifying concrete. The Poisson's ratio of solidifying concrete for two mix designs of rapid hardening Portland cement was investigated and the results were presented.

6. Acknowledgement

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7. Reference

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