Estimated the amount of air void in concrete using image processing technique

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Abstract

Image processing methods have been widely used in civil engineering recently. Image processing is reproducing the processes people got via their own vision system by digitizing. The aim of this study is to define air void values of different concrete specifies with image processing methods. With this purpose seven different concrete series have been produced by using different water/cement rates. Physical and mechanical tests have been applied on the samples acquired. Additively air void ratios have been calculated after section images obtained from hardened concrete surfaces are processed. Relations between the results obtained as a result of image processing method and pressure resistance values of the acquired concrete samples have been examined.

Consequentially it has been observed that air void values in the concrete obtained by using image processing techniques may be estimated with a high correlation.

Introduction

It is an inevitable factor that materials forming the concrete should have good quality, proper material rates should be used; fitting, densification and cure processes of concrete should be applied perfectly in order to obtain concrete, the most popular construction material, in a good quality. Even if concrete which is in touch with outside and has water in its voids has very good quality, it cannot show adequate resistance against iterant freezing-resolution phenomena [1]. Theoretically, minimum water amount necessary for hydration in Portland cement is approximately 25% of the cement’s weight. Added water after this process is necessary for penetrability and compressibility and adding water more than necessary reduces concrete’s quality by increasing porosity of hardened concrete. As a result additional water which is used in the concrete mixture comes up as air void in a hardened concrete [2]. Entrapped air voids are voids which are included involuntarily (by itself) in the concrete and in arbitrary forms and which range arbitrary while mixing and placing fresh concrete. Air voids entrapped in a firmly fixed concrete are generally less than 2% [3]. There may be a relation between entrapped air voids which are greater than entrained air voids. And in air contents greater than 5% in the concrete, pressure resistance and strength reduce significantly due to increasing discontinuity, voids and reducing mechanical sticking between paste and large aggregates [4].

There are several methods for finding entrapped air content in the concrete. Volume method or pressure method is used in order to define air amount in fresh mix concrete. Air entrainment meters are used for measuring air amount in fresh mix concrete. In addition air amount can be measured by unit weight method [3]. New methods have been tried for measuring air parameters in fresh mix concrete. By means of AVA (airvoidanalyzer) distribution of entrained air voids may be found when the concrete is fresh [5]. Air parameter measurements in hardened concrete are applied according to ASTM C 457 standards. The test is applied by observing air voids in the prepared plane concrete surface via the condenser. In this standard calculating air parameters in the concrete takes a long time [3]. New methods exist in order to define air voids automatically. In RapidAir 457 system, which is one of them, plane concrete surface is prepared in private so air voids seems white and the other surface seems black. Surface which is prepared with system video camera is scanned and air parameters are found thanks to computer [6]. Besides image processing techniques are began to be used in defining air amount in the hardened concrete thanks to rapid developments in computer technology and image processing techniques [7-18].

In the study seven different concrete types have been obtained by using 7 different W/C ratios which could change between 0.79 and 0.37 in order to define air amount in the hardened concrete. Arial ratio of air voids and air void number have been calculated from the images which are obtained from hardened concrete surfaces. Relations between results acquired by image processing technique and pressure resistance of produced concrete samples have been examined. As a result, it has been observed that air voids in the concrete obtained by using image processing techniques may be estimated with a high correlation.

Materials and method

Materials

Within the context of experimental studies aggregates which were provided from a stone crusher plant in Güneykent, Isparta and broken in four different sizes were used in concrete manufacture. CEM I 42,5 R Portland cement was used as a binding material in concrete manufacture.

Method

Preparation of experiment samples

Concrete mixtures were prepared according to TS 802 (2009). Aggregate's biggest particle size was selected as 16mm. Aggregate granulation stays in the 4^{th} religion as indicated in TS 802 (2009) [19]. Granulometry of the mixture was selected in such a way that 30% was 8-16 mm, 30% was 4-8 mm, 10% was 2-4 mm and 30% was 0-2 mm. W/C ratio changed from 0.79, 0.69, 0.61, 0.54, 0.47, 0.42 to 0.37. Prepared fresh concretes were poured into cube blocks whose sizes were 100x100x100 mm by applying vibration in the vibration table. Table 1 shows material amounts in 1 m^3 concrete for each line and concrete codes according to concrete mix calculation.

Table1 Theoretical material amounts in $1m^3$ concrete (Kg)

Code	W/C	Water	Cement	Aggregate 0-2 mm (30%)	Aggregate 2-4 mm (10%)	Aggregate 4-8 mm (30%)	Aggregate 8-16 mm (30%)
N1	0.79	222	281.0	550.1	183.4	540.1	540.1
N2	0.69	222	321.7	539.2	179.7	529.4	529.4
N3	0.61	222	363.9	527.9	176.0	518.4	518.4
N4	0.54	222	411.1	515.3	171.8	506.0	506.0
N5	0.47	222	472.3	499.0	166.3	489.9	489.9
N6	0.42	222	528.6	484.0	161.3	475.2	475.2
N7	0.37	222	600.0	464.9	155.0	456.5	456.5

Four concrete samples were produced for each series and three each of them were used for pressure resistance for 28 days and one of them was used in order to get its section images. The concretes were produced in compliance with the standards and samples were waited in the curing pool until the day when experiments would be carried out. Experiments of visible porosity, water absorption, ultrasonic pulse velocity and pressure resistance were carried out in the obtained samples.

Preparation of the samples for image processing

Concrete samples whose sizes were 100×100×100 mm and which were waited in curing for 28 days were separated into 4 slices by means of a specimen cutting machine. Their sizes were 20mm, 30mm, 30 mm and 20 mm and each one of them were vertical to concrete pouring direction. One surface apiece was obtained from the section surface of pieces numbered 1 and 4 and two surfaces apiece were obtained from the pieces numbered 2 and 3. In total 6 surfaces were obtained.

A mechanism comprising of tripod, Conan EOS450D digital camera, cube light and lights was built for getting digital images of section surfaces (Figure 1). Images of the concrete surfaces cut by using 12.2 megapixel digital camera were obtained via the mechanism. After the surfaces of the samples were dried, their jpg spanned images having 4272×2848 pixel sizes, which were in RGB color mode, were obtained. All of the imaging shoots on the concrete samples were performed in the same height and light environment on the sample surface.

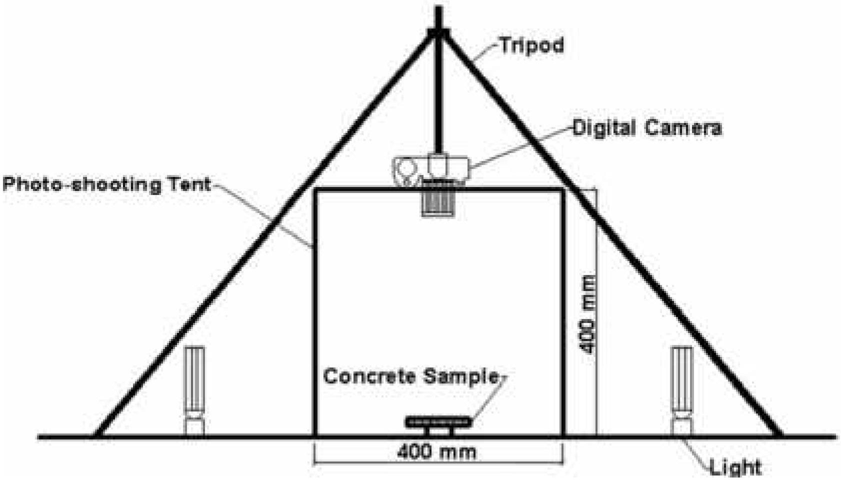

Figure 1 Mechanism built for getting digital images

Image processing steps

Obtained section images were pretreated and their image sizes were kept to be in the same size owing to open-source coded UTHSCSA Image Tool (Version 3) and image processing analysis were performed with the following processes via mentioned program.

Images in the same sizes were transformed from RGB color mode to 8 bit grey level images. Colorful images (RGB- Red, Green, Blue) were transformed to grey toned form by using equation (1) [20].

$$Gr = 0.299 * R + 0.587 * G + 0.114 * B \qquad (1)$$

Where,
Gr : Grey color value in each pixel,
R : Red color value in each pixel,
G : Green color value in each pixel,
B : Blue color value in each pixel.

Grey level images may get color values from 0 to 225. Value 0 represents black, value 128 represents grey and value 255 represents white color [20]. Figure 2 shows an image transformed into grey level. Histograms of grey level images were removed and so various data about image was removed from histogram.

Afterwards, images were transformed into doubled (binary) images. In binary images each pixel has value 0 or 1. 0 represents black and 1 represent white. Each pixel takes up 1 bit in those images. Binary images are generally used in showing finger prints, architectural plans and written texts [21]. Threshold value chosen visually by the user is applied for the image to transform into binary form (Black-White). The threshold may differ from image to image. Basyigit et al. (2012), in their study, calculated air voids, aggregate and cement matrix percentages from section images by using image processing technique [9]. They accepted grey color value which was from 0 to 63 as air void. As a result of their analysis they indicated that threshold value they identified represents aggregate, cement and air amount in the concrete mix successfully. Therefore, threshold value which would be applied for defining air void within the context of the study was chosen as 64 for equation (2) (Figure 3).

$$\text{Color } (x,y) = \begin{cases} \text{Color } (x,y) < 64,\ 0,\ \text{“}\textit{Black}\text{”} \\ \text{Color } (x,y) > 64,\ 1,\ \text{“}\textit{White}\text{”} \end{cases} \qquad (2)$$

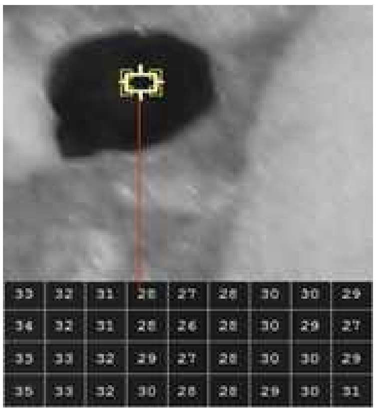
Figure 2. Grey level image

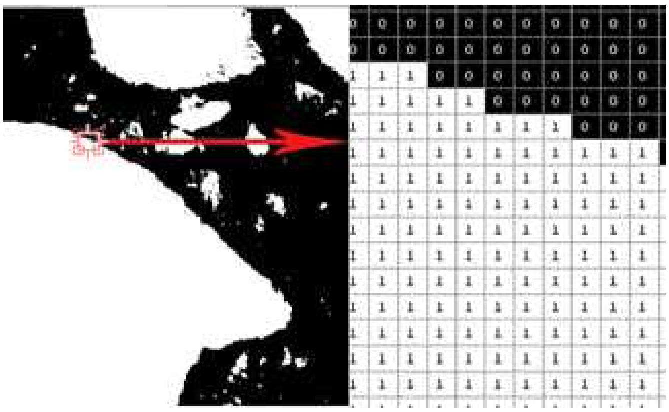
Figure 3. Doubled (Binary) image

By virtue of equation 2, the part having air voids from section images were transformed into black and the other parts were transformed into white color. Areal ratio of the voids in the section and void number were calculated on binary images.

Findings

Table 2 shows experiment results belonging to obtained concrete serials.

Table 2 Hardened concrete experiment results

Concrete Codes	W/C	Average compressive strength (MPa)	Average ultrasonic velocity (km/s)	Average water absorption (%)	Porosity (%)
N1	0.79	24.0	4.25	5.18	11.75
N2	0.69	27.1	4.33	5.29	11.95
N3	0.61	34.0	4.10	4.58	10.31
N4	0.54	36.0	4.70	4.38	9.96
N5	0.47	44.8	4.40	4.04	9.24
N6	0.42	48.7	4.30	4.00	9.14
N7	0.37	53.2	4.48	3.49	8.04

When examining Table 2 it is observed that pressure resistance of the concretes increases as W/C ratio decreases, according to the results of ultrasonic pulse velocity quality of N4 coded concrete is perfect and quality of other concretes are good.

When examining water absorption ratios, it is seen that the highest value belongs to N2 series concrete with 5.29 % and the lowest value belongs to N7 with 3.49%. It is seen that water absorption value falls as W/C ratio decreases. Water absorption amount of the concrete depends upon the pores' situation in the concrete and aggregate as much as porosity. In other words if the pores are half-open or completely closed, the concrete will absorb less water. If the pores in the concrete or aggregates are open, they will have water absorption competency as much as porosity rate [22]. When porosity values are examined, it is observed that water absorption ratios of concrete series have values from 5.29% to 3.48% while porosity values of the same series range from 11.95% to 8.04%. As it is seen, water absorption ratios are nearly as much half of visible porosities. It may be conferred that nearly 50% of the pores in the series comprises of half-open or completely closed.

Table 3 shows the results obtained as a result of image processing.

Table 3 Image processing results

Concrete Codes	**Sectional Surface**	**Total Air Voids**	**The ratio of the total area of the section void area (%)**		**Concrete Codes**	**Sectional Surface**	**Total Air Voids**	**The ratio of the total area of the section**

N1	1	168	0.33
	2	207	0.13
	3	78	0.22
	4	149	0.15
	5	271	0.13
Mean		**174.60**	**0.19**
Standard Dev.		**71.37**	**0.09**
N2	1	151	0.38
	2	170	0.27
	3	95	0.32
	4	137	0.18
	5	118	0.19
	6	30	0.13
Mean		**116.83**	**0.25**
Standard Dev.		**49.84**	**0.09**
N3	1	47	0.08
	2	649	0.30
	3	98	0.46
	4	181	0.37
	5	147	0.36
	6	96	0.35
Mean		**203.00**	**0.32**
Standard Dev.		**223.31**	**0.13**
N4	1	123	0.21
	2	557	0.72
	3	49	0.13
	4	158	0.56
	5	118	0.14
	6	552	0.66
Mean		**259.50**	**0.40**
Standard Dev.		**231.23**	**0.27**

			void area (%)
N5	1	997	0.38
	2	203	0.83
	3	377	0.42
	4	355	0.51
	5	99	0.79
	6	305	0.65
Mean		**389.33**	**0.60**
Standard Dev.		**315.19**	**0.19**
N6	1	NA	1.76
	2	1399	0.58
	3	3526	1.20
	4	350	1.12
	5	1928	0.78
	6	1366	1.08
Mean		**1713.80**	**1.09**
Standard Dev.		**1162.97**	**0.40**
N7	1	1782	0.83
	2	388	0.95
	3	835	1.03
	4	467	0.88
	5	1691	2.95
	6	173	0.68
Mean		**889.33**	**1.22**
Standard Dev.		**690.70**	**0.86**

When table 3 was examined it was seen that the lowest air void percentage in terms of its averages was obtained from N1 coded concrete and the highest air void percentage was obtained from N7 coded concrete.

Conclusions and suggestions

By using the method in this paper void amounts of various concretes may be defined and compared. By this way, parameters affecting the distribution may be presented more transparently. According to ASTM C 457 standard, as analyses are determined visually by observing air voids in prepared plane concrete surfaces via microscope, the analysis may not be sensitive adequately and have some problems like human mistakes. Additively, calculating air parameters in the concrete may have a long time. By means of the technique air voids may be defined automatically and the results may be given as computer based objectively.

In construction technology image processing will also be frequently used in the future as in today. In this context, the developed method will contribute to related studies. By using numerical image processing techniques it will be possible to solve many engineering problems such as influence degrees of parameters affecting material's properties.

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