DETECTION OF BUGHOLES USING IMAGE PROCESSING TECHNIQUE IN HYBRID CONCRETE

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Abstract- Concrete is the most widely used construction material and its strength is affected by bugholes, caused by air entrapped in concrete, which can be removed by different admixtures and heavy compaction techniques. However, in this study waste material like silica fume (SF) and fly ash (FA) are used to remove the bugholes without compromising the compressive strength of concrete. Image Processing (IP) technique was used not only to detect the bugholes, but also to determine the area of bugholes in hybrid concrete. 24 cylinders with six different mix ratios were cast with 0%, 15%, 25% of SF, and FA as cement replacement material in concrete. 12 of them were tested in compression and 12 of them were cut into 03 slices for images. The results show that compressive strength is increased with the increase in %age of SF and FA, while the % age of bugholes decreases with an increase in %age of SF and FA.

Keywords- Bugholes Concrete, Compressive Strength, Fly Ash, Image Processing, Silica Fume.

1 INTRODUCTION

Concrete is one of the most frequently used building materials. Concrete is the composition of cement fine particles, sand, and coarse aggregate [1], where cement is the most costly material. Cement production and demand are increasing day by day which causes an increase in the production of CO_2 [2]. To reduce the cost of cement waste materials [3], cement replacement materials like silica fumes (SF), fly ash (FA), and GGBS is used to produce hybrid concrete mixes having several benefits such as low production cost, reduction in CO_2, increase environmental sustainability, and long term performance [4, 5]. Fly ash affects the compressive strength and workability of concrete. Compressive strength of concrete containing fly ash decreases at an early age then increases concerning the time at a certain level. Workability of the fly ash concrete was better than the one of simple mix concrete [6]. Toutanji et al. [7] studied the influence of silica fumes on the compressive strength of cement paste and mortar. The results of their study showed the compressive strength of concrete increased with an increase in silica fume usage and it depends on the bugholes on the surface of the concrete.

Image processing is the application of performing operations on image to acquire certain information on or from the image. Image digitization is one of the techniques of image processing in which an image is converted to a digital form where each digit in the image matrix is representing the intensity of color on the surface of that image. Jiangu et al. [8] worked on two-dimensional image analysis method for evaluating coarse aggregate properties and its distribution in concrete on self-consolidated concrete mixed with fly ash of class C and F and measured the aggregate area ratio (AAR) by using the least area rectangle (LAR) technique. Bugholes are the surface voids that are due to the migration of entrapped air during the pouring of concrete, which may affect the surface of the structure of concrete. Liu et al. [9] used image analysis tool MATLAB for the detection of bug holes, area ratio, and diameter of bug holes.

Several studies have been conducted in past using image processing to investigate bugholes but those mainly focus on plain concrete and smooth surface of the concrete. In this paper, a two-dimensional image processing method is used to detect bugholes and to find the percentage of bugholes on a concrete surface with SF and FA as cement replacement material. The influence of SF and FA on bugholes and compressive strength was also investigated. SF and FA were replaced by 0%, 15%, and 25% weight of cement. 24 concrete cylinders of dimension 300 mm × 150 mm were fabricated at 14 days and 28 days against water cement ratio of 0.5 and 0.6. Half of the total specimens were tested in compression and the other half were cut into three slices of each specimen. The top and bottom surfaces of the slices of the concrete specimen were photographed in a cabin. Digital images of the surfaces of slices were converted to grayscale, cropped at the center portion of the concrete surface, and thresholded in MATLAB. Bugholes on the top and bottom surface of each slice were detected and their area was also calculated. This technique can be utilized to determine bugholes presence in concrete, determine the ratio of bugholes, and can also be used to estimate the quality of concrete through the information of bugholes obtained from the images of concrete.

2 EXPERIMENTAL PROCEDURES

2.1 Specimen Preparation

Six concrete mix ratios containing 0%,15%, and 25% of fly ash of class F and silica fume were used to prepare 24 concrete cylinders with water cement ratio of 0.5 and 0.6. Two concrete cylinders from each mix ratio were cured at 14 days and 28 days. The chemical composition of the material is given in Table 1 and mix ratios of specimen preparation are given in Table 2.

Table 1-Chemical Composition of Cement, SF, and FA

Chemical composition (%)	**Cement**	**Silica fume**	**Fly ash**
Silica	22.4	83-87	56-64
Aluminium oxide	5	1.0 (max.)	27-33
Iron oxide	4.0	2.0-3.5	1-4
Calcium oxide	63.25	1.0-1.5	1-2
Loss on ignition	0.64	4-7	9.01

Table 2-Six different mix ratios against 0%, 15% and 25% of SF and FA

Name	Mix ratios	W/C	% FA	%SF	14 days	28 days
10.5MR-0%A	1:3:6	0.5	0	0	2	2
10.6MR-0%A	1:3:6	0.6	0	0	2	2
10.5MR-15%A	1:3:6	0.5	15%	15%	2	2
10.6MR-15%A	1:3:6	0.6	15%	15%	2	2
10.5MR-25%A	1:3:6	0.5	25%	25%	2	2
10.6MR-25%A	1:3:6	0.6	25%	25%	2	2

2.2 Compressive Strength

One cylinder from each mix ratio and curing age was tested in the laboratory to obtain the compressive strength of concrete. The compressive test was carried out according to ASTM C-39.

2.3 Cutting of Specimens

The remaining specimens of concrete mix having the mix ratio as of the ones tested for compression in the laboratory were cut into three pieces of equal size for photography. Before the photography and experimental process, Ultrasonic Pulse Velocity (UPV) test was performed on each sample and was found similar to each other. The top and bottom faces of each slice of a specimen are shown in Figure 1.

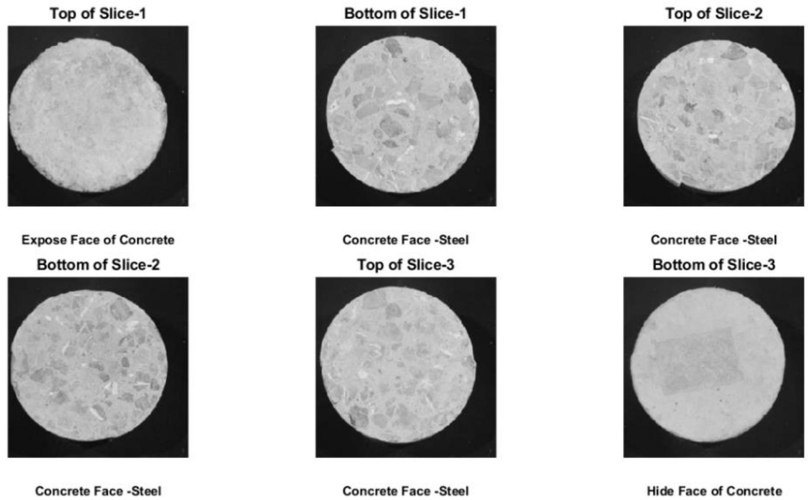

Figure 1- Top and Bottom faces of the slices of concrete cylinder

2.4 Image acquisition

A non-transparent cabin was built to form the test setup and an artificial illumination system with appropriate light intensity was installed inside the cabin. The cabin was particularly made to take photos of samples under a fixed light intensity of 2100 lux. Using daylight is not an appropriate method as it cannot maintain the same illumination for each photo. The image setup was made in a small room of dimension 2.5 m × 2.5 m. Two 30-watt LED lamps were mounted on the projector facing towards the surface of the concrete slice. Images were captured using digital camera NIKON D3300 fixed at a height of 300 mm above the concrete surface [1].

2.5 Image processing and detection of bugholes

Digital images were imported into MATLAB 2018 and converted to grayscale images using Eq. (1). The grayscale image contains shades of gray colour throughout its entire region. After conversion to grayscale, the images were centered and cropped to remove the black part of the figure which is shown in Figure 1. A pixel is the basic unit of an image with values ranging within [0, 255]. A zero value represents the black color while the 255 value denotes the white color [10]. Values in between are different shades of gray. Cropped images were thresholded with the OTSU threshold method and voids that were detected on the concrete surface are shown in Figure 2. Mask images of the cropped images, as shown in Figure 3, were also generated to calculate the area of the voids using Eq. (2).

$$Grayscale = 0.2980 * R + 0.598 * G + 110 * B \quad (1)$$

In Eq. (1), R denotes red, G denotes green and B represents the blue color. Each color value ranges within [0, 255].

$$R_b = \frac{S_b}{S} \quad (2)$$

where R_b is the ratio of bugholes, S_b is the sum of white pixels obtained from void image and S is the sum of white pixels obtained from mask image.

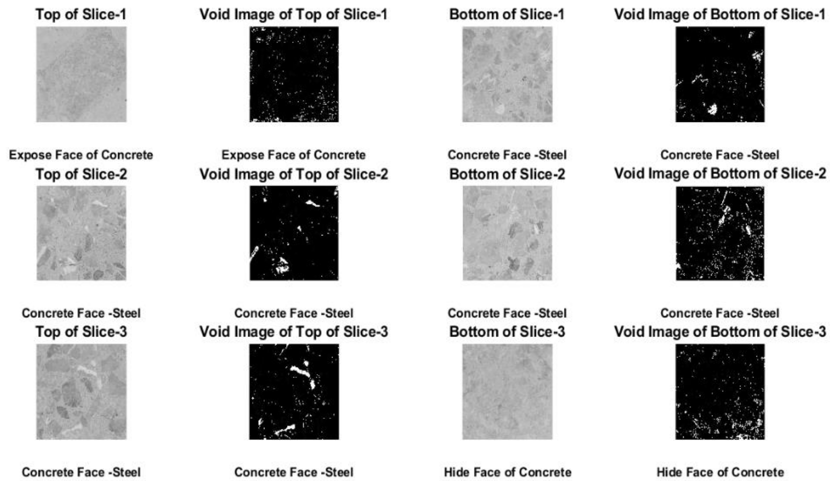

Figure 2- six face of a concrete specimen with bugholes identified images

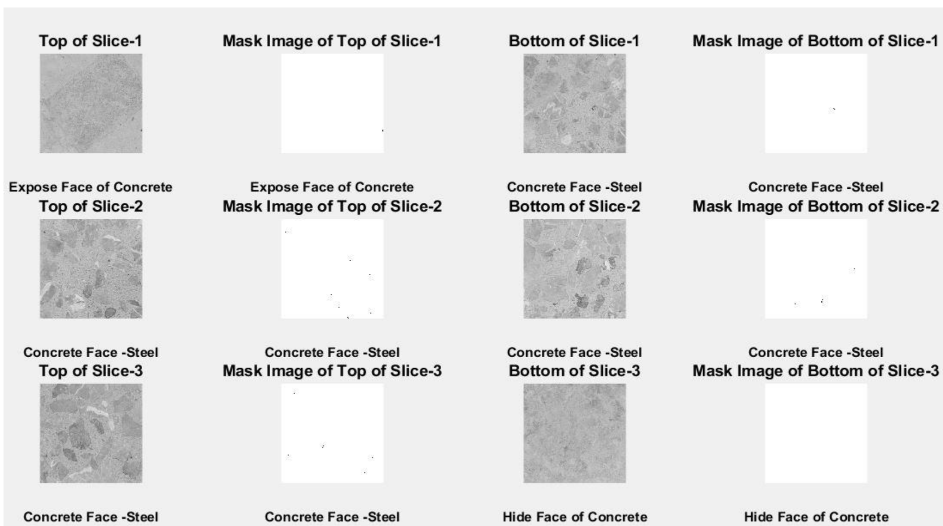

Figure 3- Mask generated images of six faces of concrete cylinder

3 Results and Discussions

3.1 Influence of Mix Design ratios, W/C, FA and SF on compressive strength

Graphical representation of the relation between mix ratios and compressive, W/C ratio, and amount of additive is displayed in Figure 4. It can be seen that the compressive strength was lower at the age of 14 and increases at the age of 28 days. Pozzolanic activity of SF and FA produces additional calcium silicate hydrate which contributes to the strength of concrete. The increase in fc at a later age was mainly due to the pozzolanic activity of FA which starts at a later age while the pozzolanic activity of SF starts at an early age. The compressive strength plot in these graphs showed that compressive strength decreases with an increase in W/C. Compressive strength of concrete with SF and FA decreased in early age specimen but a significant increase in compressive strength was noticed in a specimen of 28 days. With 0% of SF and FA and W/C 0.6, the compressive strength of specimen is 10.20 MPa while a similar specimen with 15% of SF and FA has a compressive strength of 10.10 MPa [11]. The results showed that partial replacement of cement with silica fume had a significant effect on the compressive strength of the cylinder. The strength of concrete increases rapidly with an increase in the silica fume content [12].

3.2 Effect of FA and SF on bugholes

Figure 5 illustrated that by increasing the amount of SF and FA, there is a significant reduction in the % of bugholes[13]. SF is finer material than cement and FA particles have size almost the same as that of cement particles so they fill the micro voids in paste improving the packing of aggregates in concrete. Also, bugholes are not constant throughout the entire length of the concrete cylinder which can be noticed in the graph higher at the top face and lower at the bottom face of the slice of the concrete cylinder.

3.3 Effect of curing days on the Bugholes

From the obtained results it was seen that bugholes presence is also affected by the curing age. Specimens with 14 days curing age had a greater amount of bugholes as compared to the specimens cured at 28 days with the same specifications. As the number of bugholes decreased in 28 days samples, the compressive strength of the concrete was higher than that of samples cured at 14 days [14, 15]. Graphical representation of the effect of curing age on compressive strength can be noticed from Figure 4 and the effect of curing on bugholes can be seen Figure 5. Variation in histograms of six faces of the same specimen in Figure 6 depicts the void ratio not constant across the length of concrete specimen.

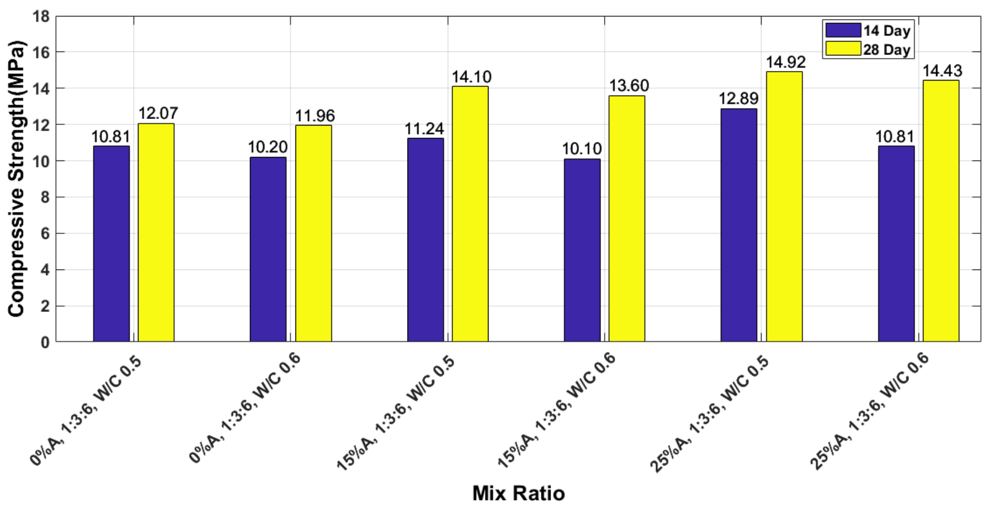

Figure 4-Compressive strength of mix ratio of concrete at 14 days and 28 days with 0%, 15%, 25% SF and FA

4 Practical Implication

Construction accepts the fact that bugholes problem is a major problem that may tend to develop crack with time so it needs to be addressed carefully. Many techniques such as surface roughness measurement techniques and pressure differential technique which are costly, require a special tool or least effective. So the image processing technique may be easily adapted in the construction industry being inexpensive, easy to use, and requires less human effort.

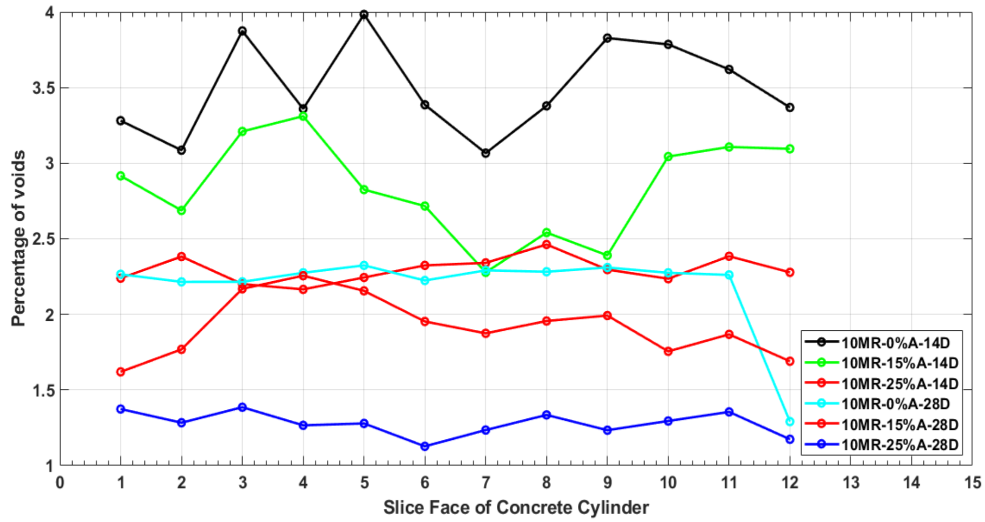

Figure 5-Percentage of the void ratio of six mix ratios of concrete with 0%, 15%, 25% SF and FA at 14 days and 28 days

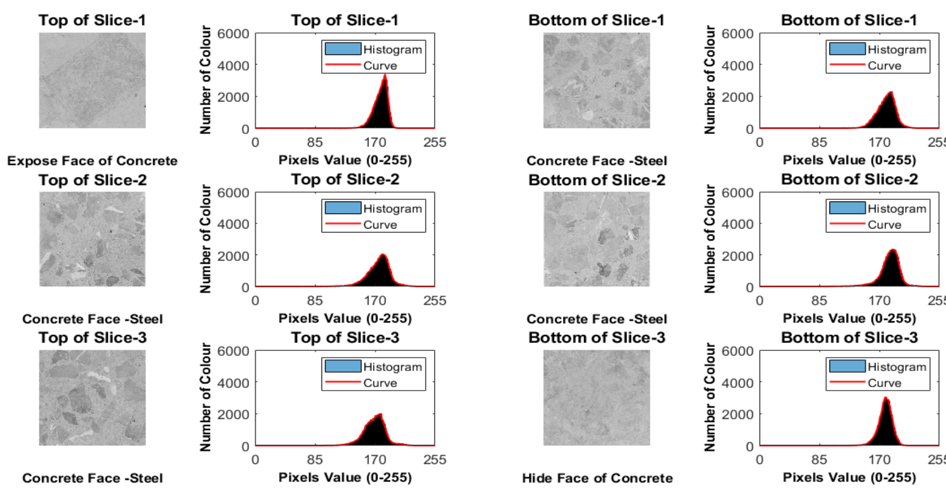

Figure 6-Histogram of six faces of the same concrete specimen showing the different number of bugholes

5 Conclusion

This paper mainly studies the detection of bugholes through images, the effect of SF, and FA on bugholes and the compressive strength of the specimen.

1. The image processing (IP) technique developed in this study can be used to obtain information on the existence of bugholes in concrete through images.
2. The results show that the IP technique can be utilized to detect bugholes in concrete and to determine the percentage of bugholes on the concrete surface.
3. Quality of concrete containing silica fume and fly ash can be evaluated based on information obtained from images of the concrete through this technique.
4. The compressive strength is decreased at the age of 14 days and it increases at the age of 28 days with concrete containing silica fume and fly ash

5. It is also observed that with the increase in the percentage of silica fume and fly ash concrete, bugholes initially increase and then decrease.

6 Research significance

FA and SF are eco-friendly and environmentally sustainable pozzolanic materials. The use of CRM reduces the production of CO2 and is inexpensive. The conventional way of identification of bugholes such as surveying is and inspection of high rise buildings is costly, labor-intensive, and may subject to human error. The image processing technique can detect bugholes easily through the image of the concrete surface with the help of a computer.

7 Future Work

In this phase of work, bugholes have been studied based on images of the horizontal cut surface of the concrete cylinders. In the next phase, slices of the concrete cylinders will be cut also vertically and bugholes will also be studied from the images of the vertical cut surface of the concrete specimens. Moreover, microscopic images of both surfaces will be captured to study bugholes. The focus of the study will be on (i) detection of bugholes through image processing, (ii) prediction of the percentage of bugholes through ANN, and (iii) classification of bugholes using CNN based on the diameter of bugholes.

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