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Factors influencing bugholes on concrete surface analyzed by image processing technology

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HIGHLIGHTS

- The influence factors on the bugholes are quantitatively analyzed by image processing technology.
- The area ratio, size distribution and maximum diameter of bugholes are evaluated.
- The area ratio and the maximum diameter of bugholes have different influencing factors.
- Appropriate mix proportions and vibration time is advantageous to reduce the bugholes.

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ABSTRACT

Bugholes are surface voids that result from the migration of entrapped air to the fresh concrete-formwork interface. The influencing factors, such as mix proportions and construction technology, on surface bugholes are quantitatively analyzed by image processing technology in this paper. The results show that the bughole area ratio of concrete and the maximum diameter of bugholes can be reduced by the methods of controlling the W/C ratio, superplasticizer content, sand ratio and fly ash content. Compared with saponifiable oil, the template paint can effectively reduce the maximum diameter and the area ratio of bugholes. Compared with wood formwork, the concrete surface using steel formwork and PVC formwork have higher amount of small bugholes and lower bughole area ratio, but the influence of formwork on the maximum diameter of bugholes on concrete surface is not significant. The concretes with different slump, mold release agents and formworks need different vibration time in order to decrease the bugholes on concrete surface, although long time vibration can reduce the surface bugholes, but the surface bugholes are difficult to be completely eliminated.

1. Introduction

Bugholes are surface imperfections that appear as small pits and craters on concrete surface after the casting process [1]. These surface voids are primarily an aesthetic problem for exposed structural concrete and do not affect the structural integrity. However, problems do arise if the concrete surface is to be painted or if the voids reach a larger diameter. These large bugholes may become the passage of corrosive medium into the interior of the concrete, and thus affect the durability of concrete. The adverse effects of the bugholes on the surface quality of concrete had been recognized very early, and bugholes on concrete surface are different to be completely avoided [1,2]. The factors influencing the formation of bugholes include the vibration, workability, mix proportions, formwork, release agents, temperature and so on [3]. The major portion of imperfections in concrete consolidation is the consequence of insufficient vibration, and another possible source is improper concrete composition [4]. According to [5], most bugholes were believed to consist of entrapped air resulting from incomplete consolidation of the concrete, the properties of the concrete mix affected the degree of success in expelling entrapped air, the characteristics of the vibrator and field procedures had an even greater effect.

The mix proportions of concrete are related to the rheology of concrete. The results obtained by Kwasny et al. [6] show that an increase in the water-cement (W/C) ratio and the superplasticizer (SP) content decreases the yield value, whilst the increase in the sand content has an opposite effect, and an increase in the yield value is found to increase the total content of the surface bugholes and especially those with size smaller than 1 mm in diameter. Huang et al. [7] studied the effects of air-entraining agent and

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defoamer on performance and apparent morphology of concrete, the results showed that the incorporation of defoamers reduced the fludility and the surface of concrete appeared the irregular large bugholes, and the incorporation of air-entraining agent could reduce the large bugholes, too many small bubbles were difficult to discharged quickly at a short time.

The aesthetics of concrete surface is directly correlated with the type of concrete/formwork interface [8]. Price et al. [9] compared the surface properties of concretes cast in both conventional (impermeable) formwork and in permeable formwork, and the use of permeable formwork had greatly reduced the incidence of bugholes on the formed surfaces. The results obtained by da Silva et al. [10] show that a reduction in the concrete shear stress ratio contributes to reduce the percentage of bugholes, whereas no significant difference in the concrete surface appearance is observed as a function of the investigated release agents. Several factors influence the formation of bugholes, but the most critical consideration appears to be the way in which the concrete is placed and compacted [3]. Zhang et al. [11] indicated that the vibration could make the concrete fluidization to discharge the internal bubbles in concrete, so the vibration process had an important effect on the number and area ratio of the surface bugholes.

With the development of computer technology, image processing technology has been applied to the study of the surface bugholes of concrete [6,12–14], the influencing factors of surface bugholes can be quantitatively analyzed. In this paper, the influence of mix proportions including water-cement (W/C) ratio, superplasticizer (SP) content, sand-aggregate (S/A) ratio and fly ash (FA) content, and construction technology including formworks, release agents and vibration process, on the surface bugholes of the concrete was studied by image processing technology [15].

2. Experimental program

2.1. Materials

The cement used is 42.5 ordinary Portland cement and complies with Chinese National Standard GB175-2007 [16], its density is 3.15 g/cm^3, its specific surface area is 350 m^2/kg, and its 28-day compressive strength is 45.6 MPa. The fine aggregate is river sand, and its fineness modulus is 2.6. The coarse aggregate with nominal maximum size of 25 mm is limestone gravel, and its crushing value is 8.0%. A polycarboxylate superplasticizer (SP) is used in the mix and complies with Chinese National Standard GB8076-2008 [17], its water reduction rate is 25%. The fly ash (FA) is class Ⅱ fly ash, its specific surface area is 480 m^2/kg, and its density is 2.41 g/cm^3.

2.2. Mix proportions

The mix proportions and slump of concrete are shown in Table 1.

2.3. Bughole detection

The concrete is mixed with a mixer for 2 min. The parameters of concrete molding process are shown in Table 2. When the influence of mix proportions is studied, the process of mixing, molding and vibration for all specimens is the same. When the influence of construction technology is studied, the process of mixing and molding for all specimens is the same. Mixed concrete mixture was casted in 150 × 150 × 150 mm mold, and cured in a standard curing room for 24 h after vibrated with an electric vibrating table. Each mix proportion has 3 specimens. After demoulding, concrete surface immediately was cleaned, and the photos of the concrete surface were taken except for the forming surface and the bottom surface. 12 photos are detected by image processing technology, and the area ratio (the ratio of the bughole areas to the total area of the concrete surface) and the size distribution of bugholes on concrete surface were given.

3. Results and discussion

3.1. Influence of W/C on surface bugholes

The experimental results of the influence of W/C ratio on the area ratio, size distribution and maximum diameter of surface bugholes are shown in Figs. 1–4. Fig. 1 shows that the bughole area ratio decreases firstly and then increases with the increase of W/C. When the W/C ratio is 0.55, the area ratio of surface bugholes reaches the maximum value of 1.40%, and when the W/C ratio is 0.4, the area ratio reaches the minimum value of 0.40%. It can be seen from Figs. 2–4, with the increase of W/C the amount of large bugholes decreases and the amount of small bugholes increases, the bugholes with 0–2 mm diameter increase and that with diameter more than 4 mm decrease. The increase of W/C results in the reduction of the maximum diameter of bugholes. The reduction of bugholes with diameter more than 4 mm is the reason for the decrease of bughole area ratio when the W/C ratio is 0.3–0.4. As the W/C ratio continues to increase, the increase of bugholes with 0–2 mm diameter results in the reduction of the mean diameter, but the area ratio of bugholes increases.

Table 1
Mix proportions and slump of concrete.

NO.	Materials (kg/m^3)					W/C	S/A ratio	SP	Slump (mm)
	Cement	Sand	Gravel	Water	FA				
A1	593	688	841	178	0	0.30	45%	0.05%	120
A2	571	688	841	200	0	0.35	45%	0.05%	160
A3	551	688	841	220	0	0.40	45%	0.05%	210
A4	532	688	841	239	0	0.45	45%	0.05%	210
A5	514	688	841	257	0	0.5	45%	0.05%	180
A6	497	688	841	274	0	0.55	45%	0.05%	210
B1	571	688	841	200	0	0.35	45%	0.00%	70
B2	571	688	841	200	0	0.35	45%	0.025%	145
B3	571	688	841	200	0	0.35	45%	0.050%	160
B4	571	688	841	200	0	0.35	45%	0.075%	225
B5	571	688	841	200	0	0.35	45%	0.1%	225
C1	571	535	993	200	0	0.35	35%	0.05%	250
C2	571	611	917	200	0	0.35	40%	0.05%	180
C3	571	687	840	200	0	0.35	45%	0.05%	145
C4	571	764	764	200	0	0.35	50%	0.05%	100
C5	571	840	687	200	0	0.35	55%	0.05%	110
D1	571	688	841	200	0	0.35	45%	0.05%	160
D2	513	688	841	200	57	0.35	45%	0.05%	195
D3	456	688	841	200	114	0.35	45%	0.05%	200
D4	399	688	841	200	171	0.35	45%	0.05%	140
D5	342	688	841	200	228	0.35	45%	0.05%	90