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Air-void characterisation of foam concrete

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Abstract

The pore structure of cementitious material, predetermined by its porosity, permeability and pore size distribution, is a very important characteristic as it influence the properties of the material such as strength and durability. The pore parameter could therefore be a primary factor influencing the material properties of foam concrete and an in depth look into this aspect is required to establish relationships between this and material properties. In order to evaluate these relationships it was necessary to develop parameters to explain and quantify the air-void structure of foam concrete. This paper discusses the investigations done to characterise the air-void structure of foam concrete by identifying few parameters and influence of these parameters on density and strength. A camera connected to an optical microscope and computer with image analysis software were used to develop these parameters. It is found that out of the air-void parameters investigated, volume, size and spacing of air voids have influence on strength and density. Mixes with a narrower air-void size distribution showed higher strength. At higher foam volume merging of bubbles seems to produce larger voids, results in wide distribution of void sizes and lower strength. Air-void shape has no influence on the properties of foam concrete.

Keywords: Foam concrete; Air void; Image processing; Shape factor; Fly ash replacement

1. Introduction

Foam concrete is a lightweight material consisting of Portland cement paste or cement filler matrix (mortar) with a homogeneous void or pore structure created by introducing air in the form of small bubbles. Introduction of pore is achieved through mechanical means either by preformed foaming (foaming agent mixed with a part of mixing water and aerated to form foam before being added to the mix) and mix foaming (foaming agent mixed with the matrix). The foam concrete discussed in this paper has been manufactured using performed foaming method.

The pore system in cement-based material is conventionally classified as gel pores, capillary pores, macropores due to deliberately entrained air, and macropores due to inadequate compaction. The gel pores do not influence the strength of concrete through its porosity, although these pores are directly related to creep and shrinkage. Capillary pores and other large pores are responsible for reduction in strength and elasticity etc. [1–3]. The above type of pores can be measured by the test methods viz., nitrogen gas absorption–desorption, mercury porosimetry, optical microscopy with image processing and X-ray computed tomography with image processing respectively [4]. The pore systems of autoclaved aerated concrete is classified as (i) artificial air pores, intercluster and interparticle pores [5] (ii) macropores formed due to the expansion of the mass caused by aeration and micropores which appear in the walls between the macropores [6] and (iii) micro capillaries (<50 nm and macro capillaries (>50 nm to 50 μm) and artificial air pores (>50 μm) [7]. In a similar fashion, the pore structure of foam concrete consists of gel pores, capillary pores as well as air voids (air entrained and entrapped pores) [8]. As foam concrete is a self-flowing and self-compacting concrete and without coarse aggregate the possibility of entrapped air is negligible. Empirical models have been proposed to relate porosity and strength of porous solids [9–11]. Based on these models and extending it, a few strength–porosity models have been developed for aerated concrete by Narayanan and Ramamurthy [12]

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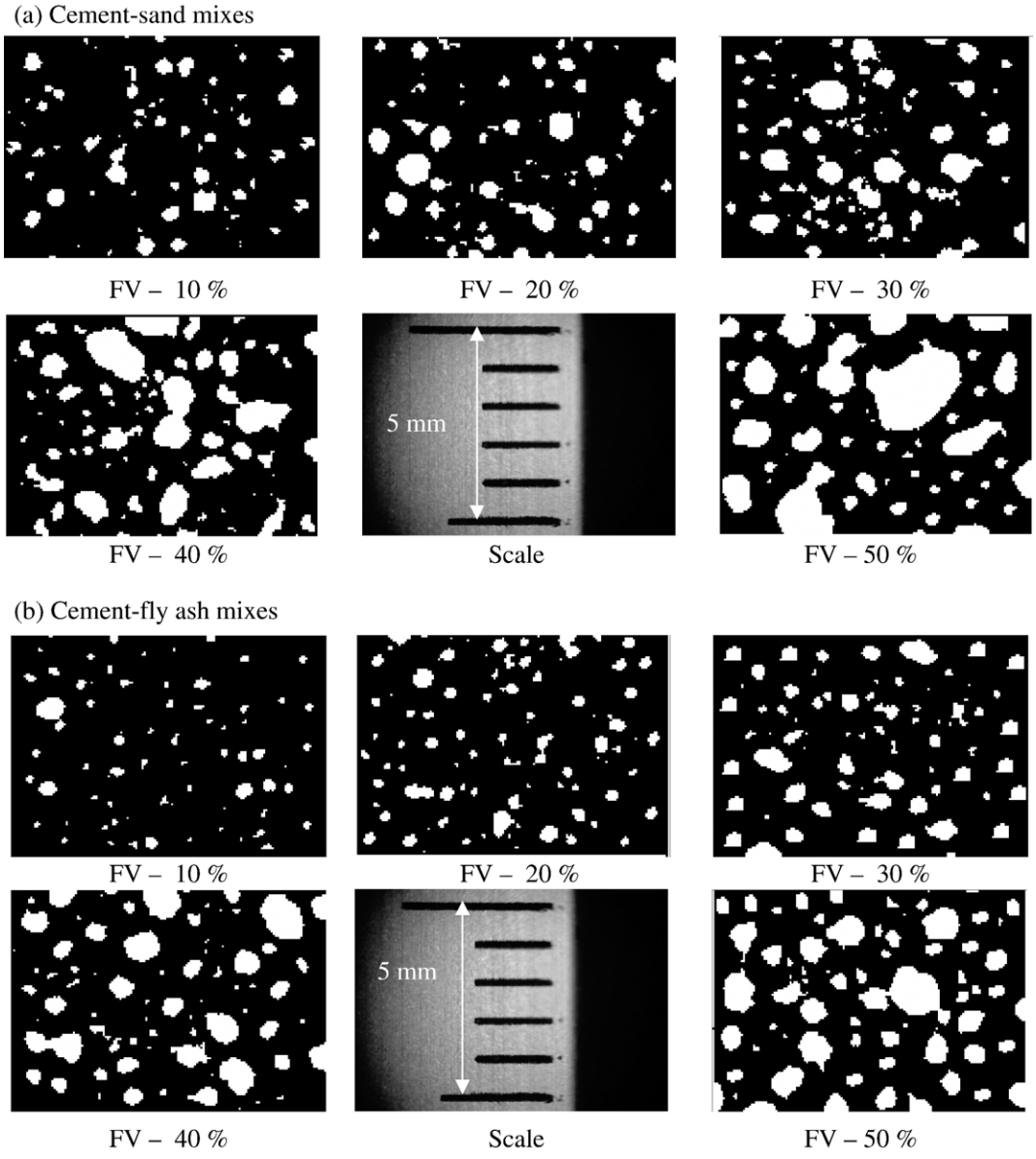

Fig. 1. Typical binary images.

and for foam concrete by Hoff [13] and Kearsley and Wainwright [14]. These models reflect the effect of porosity on the strength and may not adequately represent the pore structure.

According to Cebeci [15], air entraining agents introduce large air voids and do not alter the characteristics of fine pore structure of hardened cement paste appreciably. Kearsley and Visagie [16] reported that the air-void size distribution is one of the most important micro-properties influencing the strength of foam concrete.

The above discussion indicates that the pore parameters could be a primary factor influencing the material properties of foam concrete. Hence an in depth study is necessary to characterise the air voids through certain parameters to explain and quantify the air-void structure of foam concrete. This paper discusses the investigations on air-void structure of foam concrete by identifying few parameters like, volume, size distribution, shape and spacing and influence of these parameters on density and strength. For characterisation of pores of cement-based materials through microscopical studies, image analysis

Table 1
Variation of percentage volume of air voids with foam volume

Foam volume in the mix (%)	Percentage volume of air voids in cement–sand mix based on		Percentage volume of air voids cement–fly ash mix based on	
	Measured fresh density of foam concrete	Image analysis of hardened foam concrete	Measured fresh density of foam concrete	Image analysis of hardened foam concrete
10	8.93	11	9.23	10.43
20	18.76	18.66	19.01	18.81
30	28.90	27.79	28.61	28.13
40	37.90	36.70	38.01	36.41
50	47.34	44.44	47.94	44.84