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Mechanical properties of lightweight aerated concrete with different aluminium powder content

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Abstract. Aerated concrete is produced by introducing gas into a concrete, the amount dependent upon the requirements for strength. One method to achieve this is by using powdered aluminium which reacts with the calcium hydroxide produced upon hydration of the cement. The aim of the current study was to investigate the influence of the powder content on the mechanical properties of aerated concrete namely; compressive and flexural strengths, modulus of elasticity, density and porosity. The results indicated that an increase in aluminium content caused a decrease in the compressive and tensile strengths. It also produced a decrease in the modulus of elasticity. When the aluminium content increased, the density decreased and the porosity increased.

1 Introduction

Aerated concrete (AC) is produced by introducing gas bubbles into a conventional concrete which then produces a material of lower density. The introduction of powdered aluminium (a foaming agent) reacts with the calcium hydroxide formed on hydration of cement to produce hydrogen gas bubbles. It is not only used to insulate for sound and heat [1, 2] but is also fire resistance [3, 4]. AC can be used to decrease the dead load, earthquake effect and the size of building members. Thus, foundations become more economical and the building cost is decreased [5, 6]. However, this type of concrete has lower mechanical properties and additional cement is required for the same strength as a normal concrete [7]. Typical lightweight concrete has densities from 1000 to 2000 kg/m^3 and compressive strengths from 1 to 100 N/mm^2 [7].

Several investigations have been carried out regarding the influence of aluminium (Al) content on the compressive strength of aerated concrete [8-10]. Modulus of elasticity and flexural strength of lightweight concrete with different percentages of pumice aggregate replacement instead of sand [11] and AC with varying blocks and bricks (aerated concrete, solid and hollow block, moulded and wire cut brick) were also studied [12, 13]. Some studies into the density and porosity of AC have also been reported [10, 13, 14]. The current study,

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using laboratory testing, aims to provide a better understanding of the effect of Al concentration on the compressive and flexural strengths, modulus of elasticity, density and porosity of aerated concrete. A control of 0% will be compared with 0.25%, 0.5%, 0.75% and 1% content of Al.

2 Experimental details

2.1 Materials

AC composed of one part of CEM I/52.5N with two parts of Leighton Buzzard sand together with Al with the purity of 99.7%. The mix proportions of varying AC are shown in Table 1.

Table 1. Mix proportions of the AC with different Al contents.

Material	kg/m^3				
	Mix 1	**Mix 2**	**Mix 3**	**Mix 4**	**Mix 5**
Cement	350	350	350	350	350
Sand	700	700	700	700	700
Water	175	175	175	175	175
Aluminium powder	0	0.87	1.75	2.63	3.5
Superplasticizer (SP)	4.2	4.2	4.2	4.2	4.2

2.2 Procedure

First, cement and sand were mixed together. Then aluminum powder was added and mixed for 30 sec. Finally, warm water (55 ± 1 ˚C) with the superplasticizer were added and mixed for 2 min.

2.3 Casting and testing

100 mm cube was used for compression test. The compressive strength of the AC was determined according to the BS EN 1881 -116 [15]. Flexural strength was measured by using prisms with dimensions 40 mm cross section and 160 mm length according to the BS EN 1351 [16]. Cylinders with diameter 100 mm and length 200 mm were used for determined modulus of elasticity (E_s) according to BS EN 1352 [17]. The dry density of the AC was measured according to the BS EN 992 [18]. Porosity was measured by vacuum saturation method according to Hall [19].

3 Test results and discussion

3.1 Compressive strength

In this study, the compressive strength of AC mixtures was a function of different Al contents, which are plotted in Figure 1, and presented lower strengths when compared with the control. The lowest compressive strength was 18.6 N/mm^2 with 1% Al due to largest number of voids and lowest rate of calcium silicate hydrate (C-S-H) gel. Thus, it did not contribute sufficiently to the compressive strength. The highest strength was for control (0% Al) at 53 N/mm^2 which then decreased significantly on introduction of 0.25% Al to 32.3 N/mm^2 and then decreased slightly as the Al increased with 26 N/mm^2 for 0.5% and 23.4

N/mm^2 for 0.75% Al. Similar results were obtained by Guglielmi *et al.* [8] who reported that when the Al content increased from 0.2 to 0.4%, the compressive strength decreased because of the higher homogeneous distribution and quantity of the pores and the inter-pore struts are thinner, conferring a lower strength to the material.

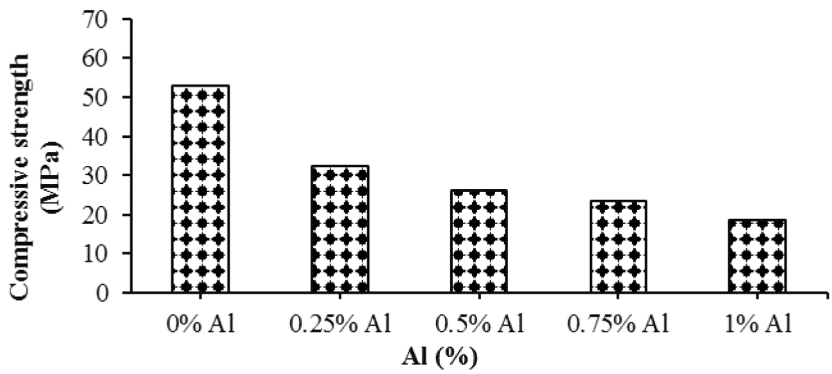

Fig. 1. Compressive strength of cube AC specimens as a function of Al content.

3.2 Flexural strength

The variations of the flexural strength of AC are presented in Figure 2 which shows that it decreases when the Al content increases. The lowest flexural strength was 3.3 MPa with 1% Al. The highest strength was for control (0% Al) at 5.5 MPa which then decreased slightly on introduction of 0.25% Al to 4.6 MPa, 4.2 MPa for 0.5% and 3.7 MPa for 0.75% Al. Similar results were obtained by [20, 21], when the flexural strength increased due to an increase in compressive strength.

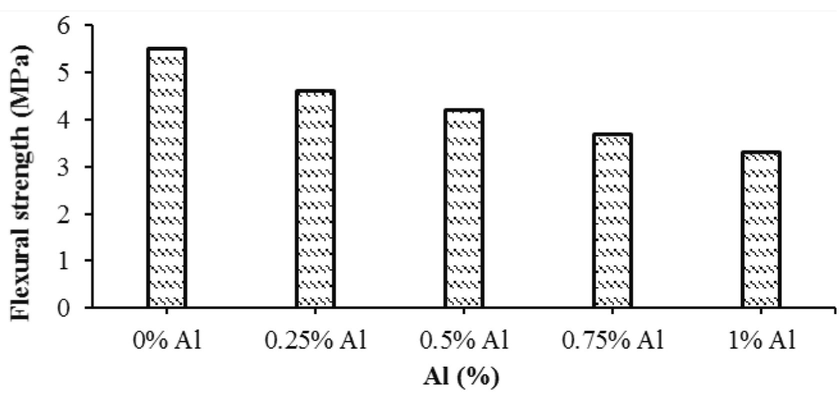

Fig. 2. Flexural strength of AC as a function of Al content.

3.3 Modulus of elasticity

The modulus of elasticity (Es) is mainly effected by the nature of the aggregates and cement paste. Additional effects are provided by the bond and arrangement between the particles [22]. Figure 3 presents the modulus of elasticity of AC with different Al content. In comparison to control, AC specimens have less stiffness due to the presence of the Al, which caused larger and more pores to be formed and reducing strength. It is clear that the AC which is obtained from high Al powder content caused a greater loss in the modulus of

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elasticity than that with lower content. The lowest Es was 7.8 MPa with 1% Al. The highest Es was for control (0% Al) at 23MPa which then decreased slightly on introduction of 0.25% Al to 18.9 MPa, 14.1 MPa for 0.5% and 9.7 MPa for 0.75% Al.

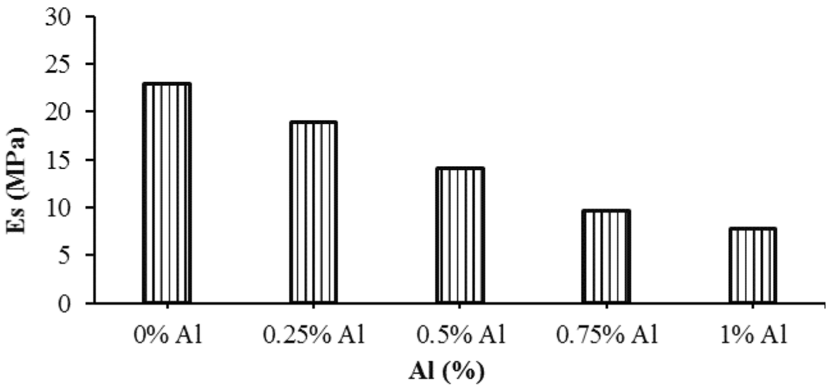


Fig. 3. Modulus of elasticity of AC as a function of Al content.

3.4 Density and porosity

The dry density and the porosity of AC samples are both a function of Al powder content as shown in Figure 4. The result revealed that the dry density varied as expected for the different Al contents. It decreased as the foaming agent percentage increased because of the higher number of pores created. The density decreased from 2102 Kg/m^3 for the control to 1841 Kg/m^3 with 0.25 % Al powder. Then it decreased gradually with the increasing Al content. The lowest density was obtained with 1% Al which was 1489 Kg/m^3. The same behaviour was observed for the porosity of the AC samples which increased from 10 % to 26 % when the Al content increased from 0% to 1%. AC samples with Al powder from 0.5 to 1% revealed the present of pores with a non-uniform shape. These were larger than those observed for AC with 0.25% Al, which indicates the coalescence of the pores in mixtures with higher Al content. Scheffler and Colombo explained the coalescence of the pore to the high reactivity of the Al powder [23]. The fracture surfaces of the AC samples with different Al contents in this study are shown in Figure 5.

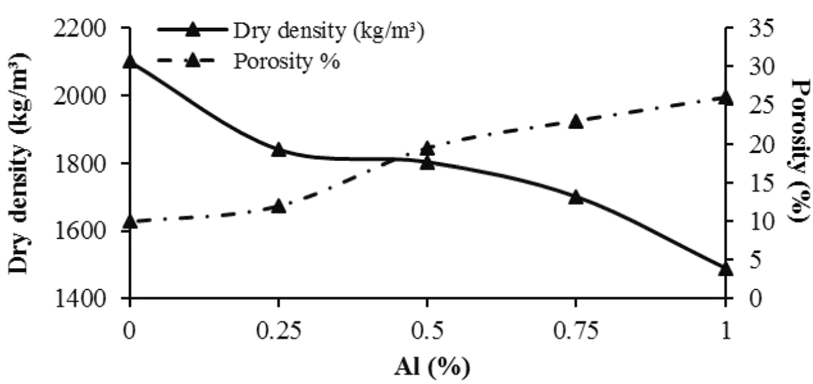
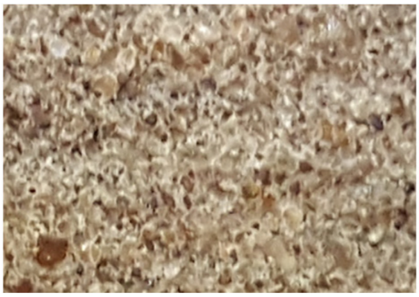
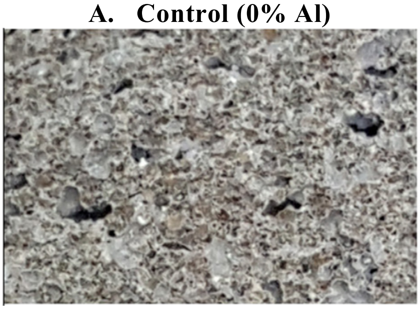
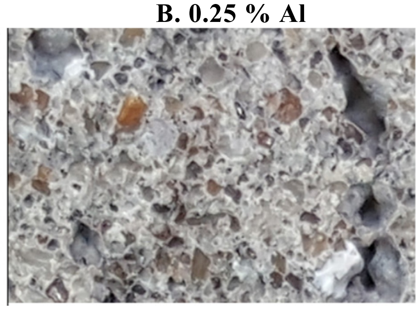


Fig. 4. Apparent density and porosity of AC as a function of Al content.

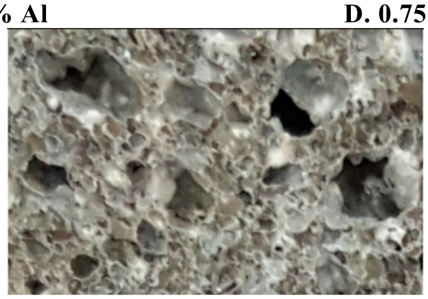


A. Control (0% Al) **B. 0.25 % Al**





C. 0.5 % Al **D. 0.75 % Al**



E. 1 % Al

Fig. 5. Fracture surface of AC samples with different Al content.

4 Conclusion

This study has shown that by adding Al powder:

1. The compressive strength of the AC specimens decreases with increasing the Al powder content. Due to the high reactivity of Al, the rate of production calcium silicate hydrate (C-S-H) gel may decrease which corresponds with the reduction in the strength.

2. The flexural strength of the AC has direct relationship with compressive strength results and it decreases as the foaming agent increases.

3. The modulus of elasticity of the AC specimens declined according to the increase of the content of the Al.

4. When the Al powder content increased, the density decreased gradually. However, the porosity increased significantly due to higher number of pores formed (Fig.5).

5. The fractured surfaces of the AC samples with the Al powder from 0.5 to 1% revealed the present of the pores with a non-uniform shape, which were larger than those observed for AC with low content 0.25%.

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