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Cellular Lightweight Concrete Containing Pozzolan Materials

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Abstract

This research studies various properties of compressive strength, water absorption, and the porosity of cellular lightweight concrete or CLC, which is pre-formed foam method made from portland cement blended with foaming agent and pozzolan materials. Uses of fly ash replace cement in the proportions 10, 20 and 30 percent by weight of binder. Constant water to binder ratio of 0.5 and unit weight of 800 kg/m^3 compared compressive strength at curing age 3, 14, 28 and 60 days. The study result that replacing cement with fly ash that is high strength on the early stage.

Keywords: Cellular lightweight concrete, compressive strength, pozzolan material, foaming agent

1. INTRODUCTION

The cellular lightweight concrete (CLC) or sometimes might often call that foamed concrete is either a cement paste or mortar, classified as lightweight concrete, in which air voids are entrapped in mortar by suitable foaming agent. By proper control in dosage of foam content, a wide range of densities between 500 to 1600 kg/m3. A study on fineness of filler type on compressive strength of foamed concrete made with cement–fly ash mix, suggesting that the inclusion of fly ash helps in achieving more uniform distribution of air voids than fine sand, is a journal paper, reference (Nambiar and Ramamurthy, 2006). The cellular lightweight concrete can be obtained for application to structural, partition, insulation wall

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and filling hole. Few studies report on the influence of pozzolan materials on the properties of cellular lightweight concrete. By using fly ash as filler (fine aggregate) instead of sand, the high volume utilization of fly ash becomes possible, thus providing a means of economic and safe disposal of this waste product. The pore system in based cement material is conventionally classified as gel pores, capillary pores, macro pores due to deliberately entrained air, and macro pore due to compaction has not enough. The gel pores not influence the strength of concrete through its porosity, although these pores are directly related to creep and shrinkage. Fly ash being finer, helps in uniform distribution of air voids by providing a well and uniform coating on each bubbles and preventing it from merging and overlapping, is a journal paper, reference (Nambiar and Ramamurthy, 2007). This paper discusses a systematic study on the influence of filler contents on the properties of cellular lightweight concrete made using pre-formed foam method.

2. EXPERIMENTAL

2.1. Parameters investigated and mix compositions

As the experimental program was aimed at studying the effect of the filler contents on the properties like density, flow behavior, water absorption and strength of cellular lightweight concrete, the following mixes were investigated by constant water to binder ratio of 0.5 by weight. The foam required for one density of cellular lightweight concrete of 800 kg/m3 was arrived as per ASTM C 796-97. In the fly ash mixes 0%, 10%, 20% and 30% by weight of binder are instead with fly ash by use symbols of C800, FA10, FA20 and FA30, respectively.

2.2. Materials

The foaming agent used was hydrolyzed protein foam and manufactured in Thailand. The mixture has used ordinary portland cement (OPC) which its particle is shown in Fig. 1(a), no fine river sand added and class F fly ash conforming to ASTM C 618 were used. The properties of cement and fly ash used in this study are presented in Table 1 and the scanning electron microscope (SEM) image of a fly ash particle is shown in Fig. 1(b).

2.3. Details of study

Foamed concrete is produced under controlled conditions from cement, filler, water and a liquid chemical that is diluted with water and aerated to form the foaming agent. The foaming agent was diluted with water in ratio of 1 : 40 by weight, and then aerating to a density of 45 kg/m3. The specimens were removed from the mould after 24 hours then wrapped with plastic film until near the time tests. The compressive strength, dry density and water absorption were determined. Even for mixes with fly ash at the age 3, 14, 28, and 60 days for five samples. Strength test was conducted so that comparison with the fly ash contents mixes would be possible. Size 100×100×100 mm cubic specimens, as the recommendations in ASTM standards, cast for the study of each parameter were used for the compressive strength test.

2.4. Scanning electron microscope image

The microstructure of cellular lightweight concrete was investigated using SEM (JOEL JSM-6400). The sample were split middle portion hardened blended cement paste. Samples were submerged directly into liquid nitrogen for 5 minutes then are evacuation under pressure of 0.5 N/m2 at temperature of -40 ºC for 2 days (Galle, 2001, Konecny and Naqvi, 1993).

3. RESULTS AND DISCUSSION

3.1. Characteristic of OPC and fly ash

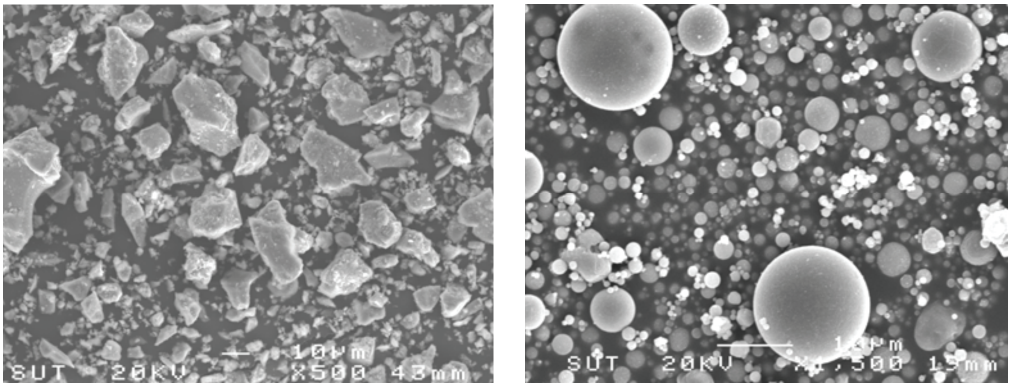
Physical properties of the materials are shown in Table 1. The specific gravity of fly ash is 3.15. The median particle size of fly ash (D50) is 14.52 µm, particle size has small sized and nearby cement particle. The chemical compositions of OPC and fly ash are given in Table 2. The main chemical composition of fly ash has total amount of SiO2, Al2O3 and Fe2O3 more than 70 %.

Table 1: Physical properties of materials used

Sample	Specific gravity	Median particle size (µm)	Blaine fineness (cm2/g)
OPC	3.15	14.75	3,600
Fly ash	2.02	14.52	-

Table 2: Chemical composition of materials used

Chemical composition (% by weight)	OPC	Fly ash
Silicon dioxide (SiO2)	19.85	43.87
Aluminum oxide (Al2O3)	4.49	26.33
Iron oxide (Fe2O3)	3.56	10.81
Calcium oxide (CaO)	66.96	12.69
Magnesium oxide (MgO)	1.36	1.23
Sodium oxide (Na2O)	-	-
Potassium oxide (K2O)	0.34	1.10
Sulfur trioxide (SO3)	2.46	2.74
Loss on ignition (LOI)	0.98	1.23
SiO2 + Al2O3 + Fe2O3	-	81.01



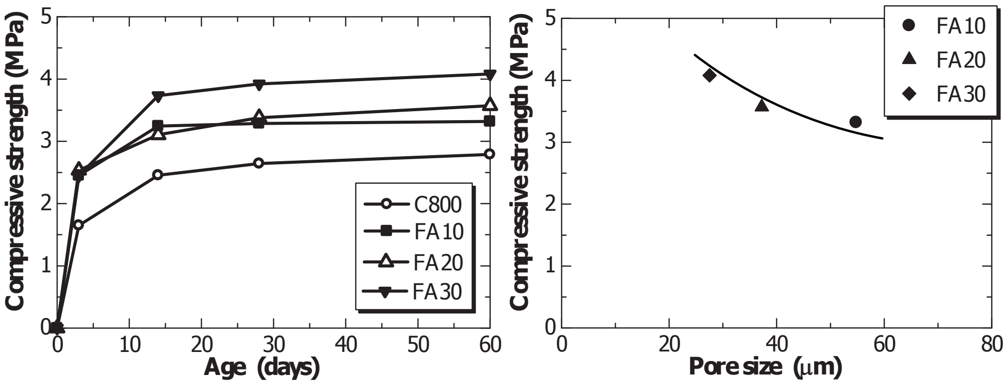
a) OPC (×500) b) Fly ash (×1,500)

Figure 1: Scanning electron microscope images of particle

3.2. Compressive strength

The effect of fly ash contents on the compressive strength of cellular lightweight concrete is presented in Fig. 2(a). For a given density, the mix with high contents resulted in higher strength than the mix with low contents and the variation is higher at higher density. Similar results have been reported in literature as (Kearsley and Wainwright, 2001, Nambiar and Ramamurthy, 2006). Fracture surface of the specimens viewed through a scanning electronic microscope with magnification factor of 100 showed that there was a comparatively uniform distribution of pore in the case of cellular lightweight concrete with low contents, while the pores were connected mostly and irregular for mixes with high contents. This indicates that high contents causes clustering of bubbles to form irregular small pores and concrete is slump while it is setting. Thus it can be concluded that low contents results in uniform distribution of bubbles and hence results in lower strength than high contents at a given density, (Kearsley and Wainwright, 2002) reported similar observations on the effect of density on the strength of lightweight concrete.

In order to study the effect of replacement of cement with fly ash, the relationship between pore size and compressive strength for cellular lightweight concrete mixes with fly ash as filler is shown in Fig. 2(b). For a given density, an increase in fly ash content results in higher strength. Apart from pozzolanic activity of fly ash, the lower requirement of foam volume for a given density of foam concrete will also contribute to strength enhancement by reducing the pore volume and facilitating uniform distribution of pores. Reference (Chindaprasirt et al., 2005, Nambiar and Ramamurthy, 2007) observed a similar enhancement in strength due to fly ash and this was attributed to the development of strong inter particle bond between the gel matrix and the fly ash particles.



a) Strength vs age b) Strength vs pore size at 28 days

Figure 2: Effect of fly ash content on strength and pore size

3.3. Water absorption and porosity

Table 3 shows the variation of compressive strength with water absorption of cellular lightweight concrete. It is noted that, unlike conventional concrete, water absorption increases with compressive strength. A possible explanation can be that for a given cellular lightweight concrete mix, increased density corresponds to an increase in paste volume of capillary pore and reduction in foam volume of artificial pore. However, the compressive strength and water absorption increase with density of cellular lightweight concrete. Therefore, for a given cellular lightweight concrete mix, water absorption mainly depends on capillary pore volume and the volume of artificial pores governs the compressive strength and density, (Narayanan and Ramamurthy, 2000) reported similar conclusions on strength of artificial pore dependency for autoclave aerated concrete.

The porosity and the water absorption at 28 days of cellular lightweight concrete can be seen in Table 3 and Table 4. From these Tables it can be seen that the relationship is not significantly influenced by the use of fly ash. Mixtures with replace fly ash of 30 % seem to yield marginally higher absorption than mixtures with fly ash replacement of 20 % while replace fly ash of 30 % has lower porosity. However, these differences are only small and it can be concluded that for the results available, the volume of ash used does not significantly influence the porosity strength relationship of cellular lightweight concrete.

Table 3: Compressive strength and water absorption of cellular lightweight concrete with variation of fly ash replacement

Symbol	Fly ash content (% by weight)	Compressive strength (MPa)				Water absorption (% by weight)
		3 days	14 days	28 days	60 days	
C800	0	1.65	2.46	2.64	2.79	31
FA10	10	2.45	3.25	3.29	3.32	35
FA20	20	2.53	3.11	3.38	3.57	39
FA30	30	2.45	3.73	3.92	4.08	47

3.4. Pore size distribution and microstructure

From the total pore volume and pore size distribution of cellular lightweight concrete shown in Table 4. It explained that total pore volume of 0.33 to 0.76 cc/g. The capillary pore (>0.01 µm) took 56 to 91% of total pore volume. The pore size distribution in Fig. 3, it was known that hydration reactions of cement mainly generated pores smaller than 0.1 µm. Similar results have been reported in reference as (Chindaprasirt et al., 2005). However, during foaming insert of air bubble foam, the pores generated were mostly larger than 100 µm. In adding fly ash increased the volume of pores smaller than 30 µm. This meant that cellular lightweight concrete with foaming agent mostly produced pores larger than 30 µm and thus to result in a flowable structure due to its open and connected pores. Similar results have been reported in reference as (Wang et al., 2005). Thus it can be proved in SEM micrograph.

Table 4: Porous structure of cellular lightweight concrete at 28 days

Symbol	Fly ash content (% by weight)	Pore size (µm)	Total pore volume (cc/g)	Porosity (%)
FA10	10	54.78	0.3379	59.15
FA20	20	37.23	0.7651	90.03
FA30	30	27.53	0.3325	56.38

Fig. 4 shows the scanning electron microscope images of fractured surface of cellular lightweight concrete at 28 days. In Fig. 4(a) is shown the plain cement paste, all porous structure has smoothly surface seen under the higher power microscope (×100). In Fig. 4(b),(c), there are close pores and it proved that cellular lightweight concrete had the characteristic of low water absorption under the higher power microscope (×100). In Fig. 4(d), there are connecting pores and small pores which are proved that cellular lightweight concrete had the characteristic of high water absorption.

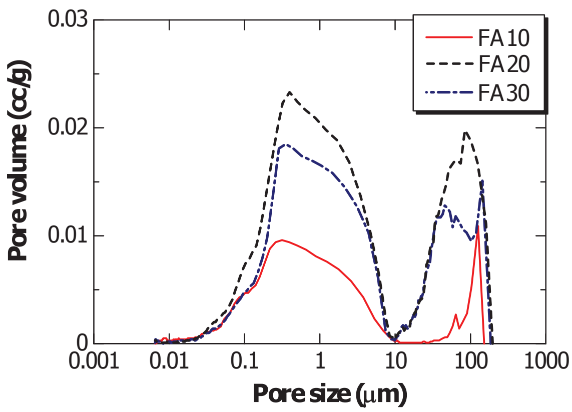
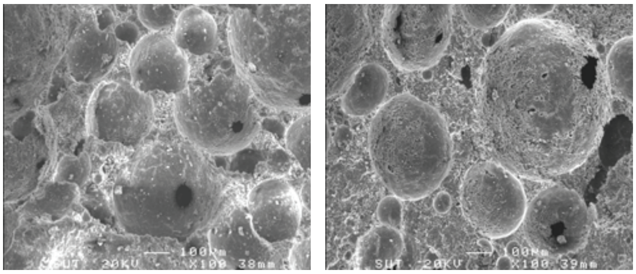
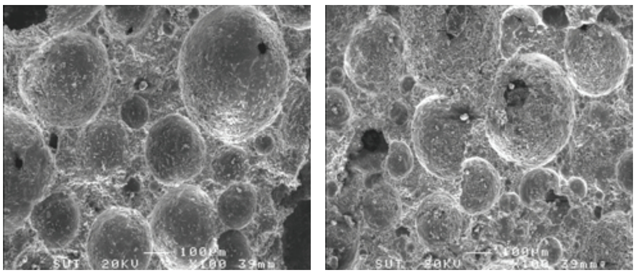


Figure 3: Effect of fly ash content on cellular lightweight concrete.



a) C800 b) FA10



c) FA20 d) FA30

Figure 4: Fractured surface of cellular lightweight concrete at 28 days (×100).

4. CONCLUSIONS

The conclusions drawn from this study and summarized below are applicable to the characteristics of the materials used and the range of parameters investigated:

1. For a given density, an increase in fly ash content of the mix results in increased strength.
2. Replacing cement with high fly ash not affect the compressive strength in early age.
3. Replacing cement with high fly ash affects the pore size decrease and cause compressive strength increased.

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