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The effects of sediment from louver edge process on the properties of autoclave aerated concrete

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Abstract*—In this study, sediment from louver edge process (LES) was used as a fine aggregate in autoclave aerated concrete (AAC) with various replacement levels (0%, 25%, 50%, 75%, and 100%) and pulverized fuel ash (PFA) was used to replace for ordinary Portland cement (OPC) at the level of 80% by weight. AAC samples were subjected to steam curing at 180°C for 8 hours. The physical, mechanical and microstructure properties of AAC were examined. Results showed that the unit weight and compressive strength decreased with increasing the amount of LES. Scanning electron microscopy (SEM) reveals the presence of platy tobermorite in the reference sample but at increasing amount of LES, lath-like tobermorite and fibrous CSH were formedThis electronic document is a "live" template. The various components of your paper [title, text, heads, etc.] are already defined on the style sheet, as illustrated by the portions given in this document. *(Abstract)

Keywords—* *Autoclave aerated concrete, Pulverized fuel ash, Unit weight, Compressive strength, Microstructure

I. Introduction

Autoclave aerated concrete (ACC) is a lightweight material which is produced from very fine aggregate, lime, water and ordinary Portland cement (OPC) with aluminium powder as a pore-forming agent [1]. The air bubbles present in aerated concrete are generated from the reaction between metallic aluminium and calcium hydroxide in the form of hydrogen gas and is illustrated in Eq 1[2].

$$2Al + 3Ca(OH)_2 + 6H2O \rightarrow 3CaO \cdot Al_2O_3 \cdot 6H2O + 3H_2(gas) \quad (1)$$

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The ACC is generally steam-cured in an autoclave at temperature between 180 and 200°C for several hours to improve the strength. The advantages of AAC over conventional concrete are the presence of air bubbles which make it lighter in weight. Consequently, lower density, lower thermal conductivity and higher heat resistance were obtained. Recent research works on ACC have aimed at the use of by-products or waste residues as cement replacement material or as inert fillers to improve the concrete properties. These by-products and waste residues include lignite fly ash, silica fume, wheat straw ash and blast furnace slag which were generated at an increasing amount each year [3]. The application of the by-products and waste residues in construction materials are of great interest.

This research aims at the use of two types of waste residues in the preparation of AAC. Sediment from louver edge process (LES) was used to replace fine aggregate such as river sand due to its high fineness and silica content (approximately 60%) whereas pulverized fuel ash (PFA) from lignite power plant was used to replace for OPC. The optimum proportion between PFA, LES and lime will be investigated. The effect of steam curing at 180°C for 8 hours on the properties of AAC such as strength, unit weight and microstructure were determined.

II. Materials

The mixture of AAC samples containing OPC, quick lime, quartz sand, PFA and, LES were prepared. LES is sediment from louver edge process, which was obtained from the glass industry. PFA used for this work was provided by the power plant located in Lampang province, Thailand. Also, quartz sand was ground to the average particle size nearly 100 µm. Aluminium powder was supported by the Super Block Company Limited. The physical properties and chemical compositions of raw materials are shown in Table 1 and 2, respectively.

Table 1 Physical properties of OPC, LES, PFA and river sand

Sample	Specific Gravity	Retain on Sieve No. 325 (% retained)
Ordinary Portland Cement (OPC)	3.13	14
Pulverized fuel ash (PFA)	2.37	19
River sand	2.59	-
Sediment from louver edge process (LES)	2.33	17

Table 2 Chemical compositions of OPC, PFA and LES

Chemical Composition (wt %)	OPC	PFA	LES
CaO	66.2	14.57	8.2
SiO_2	18.8	38.16	62.73
Al_2O_3	4.65	22	6.05
Na_2O	0.2	1.36	14.89
Fe_2O3	3.22	13.13	0.67
MgO	0.79	3.35	3.37
P_2O_5	0.07	-	-
K_2O	0.75	2.77	0.53
SO_3	-	2.87	0.84

III. Method

The reference sample was prepared from OPC, PFA, quick lime and sand. LES was used to replace sand at the level of 25%, 50%, 75%, and 100% by weight, also referred as LES25, LES50, LES75 and LES100, respectively. The aluminium powder was added at 0.7 % by weight of binder (OPC+quick lime) and water/binder was determined by the flow table method to obtain a flow of 110 ± 5%, as followed by ASTM C109 [4]. The mix proportions are shown in Table 3. The specimens were autoclave curing at temperature of 180 °C for 8 hours. At the end of the curing period, the autoclave was cooled down slowly to ambient temperature. After autoclaving, the sample specimens sizing 50 × 50 × 50 mm^3 were dried in an oven at 40°C for 24 h before strength testing.

The samples used to determine for unit weight were dried at 105°C for 24 h. The values of strength and unit weight were averaged from the five replicates to ensure the reproducibility of the data. Microstructure of the sample was examined using scanning electron microscopy (SEM, JEOL-JSM-600).

Table 3 Mix proportions of AAC containing PFA and LES

Sample	OPC (Wt %)	PFA (wt%)	Lime (Wt %)	Sand (Wt %)	LES (Wt %)	Aluminium (wt% of Binder)	W/B ratio
Reference	5	20	25	0	50	0.7	0.72
LES25	5	20	25	12.5	37.5	0.7	0.78
LES50	5	20	25	25	25	0.7	0.83
LES75	5	20	25	37.5	12.5	0.7	0.9
LES100	5	20	25	50	0	0.7	0.95

IV. Result and discussion

A. *Unit weight*

The unit weight of all samples is demonstrated in Table 4. The unit weight of the reference sample is 798 kg/m^3 and decreased with increasing the amount of LES. The unit weight of the sample containing LES was lower than the reference in the range between 1 and 8%. This can be described from the porous nature and specific gravity of LES (2.32) which is lower than quartz sand (2.59), resulting in the lower unit weight of AAC sample containing LES.

Table 4 Unit weight and compressive strength of AAC samples.

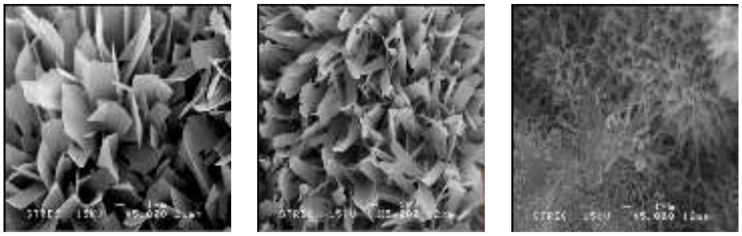
Sample	Unit Weight (kg/m^3)	Compressive Strength (MPa)
Standard [5]	800	4
Reference	798	5.28
LES25	792	4.96
LES50	782	4.69
LES75	745	4.38
LES100	737	4.17

B. *Mechanical properties*

Normally, the compressive strength is directly related to the unit weight. The compressive strength of the AAC samples with and without LES is shown in Table 4. The reference AAC sample gave strength of 5.28 MPa and decreased to 4.69 and 4.17 MPa when LES was used to replace sand at 50 and 100%. Lower strength was obtained from AAC samples containing LES could be caused by nature of LES which is highly porous and thus, requiring more water for the mixture to maintain the workability. It is generally known that sample with high water/binder (W/B) ratio causes a reduction of strength due to the increase of the water-filled pores which have not been filled with the hydration products.

C. *Microstructure*

SEM images of the reference AAC and AAC containing LES to replace for sand at 50 and 100% are illustrated in Fig. 1 a-c. Under steam curing at 180 °C for 8 hours, the platy and lath tobermorites were observed from the reference sample (Fig. 1a). It is reported that tobermorite is formed at curing temperature between 140-180 °C and Ca/Si ratio between 0.8-1.0 [6]. When LES was used to replace sand for 50% and 100%, the platy tobermorite was transformed to lath-like structure (Fig 1 b) and fibrous CSH (Fig. 1c). This could be caused by the amount of silica in the mixture was reduced and as a result, the ratio of Ca/Si increased to the level that is not suitable for the formation of tobermorite. This agrees with the strength results in that fibrous CSH gave lower strength than lath and platy tobermorite.



(a) (b) (c)

Figure 1 SEM at 8 h of autoclaving curing: (a) reference; (b) LESC 50; (c) LESC 100

v. Conclusion

The experimental results showed that the use of PFA and LES to replace for OPC and sand can produce AAC specimens and are summarized as follow:

- LES can be use to replace for sand in the production of AAC and gave either strength or unit weight that meet the requirement of ASTM C1386-07 class 4.
- The replacement of fine aggregate (sand) by LES is beneficial to energy conservation in that LES can be used directly without the need to grind. This practice can also provide an environmental friendly waste management. However, there is an advantage of LES in that the porous nature of LES increases the water requirement of the mixture.
- The introduction of LES in AAC samples can significantly reduce the unit weight.
- SEM micrographs of AAC samples reveal that the presence of LES affects the morphology of tobermorite by transforming the platy tobermorite to lath-like tobermorite and fibrous CSH

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