Construction and Building Materials 173 (2018) 220–227

Contents lists available at ScienceDirect

Construction and Building Materials

journal homepage: www.elsevier.com/locate/conbuildmat

Influence of partial sand replacement by black rice husk ash and bagasse ash on properties of autoclaved aerated concrete under different temperatures and times

Kittipong Kunchariyakun [a,*], Suwimol Asavapisit [b,*], Suthatip Sinyoung [c]

[a] School of Engineering and Resources, Walailuk University, Nakhornsithammarat, Thailand
[b] School of Energy, Environment and Materials, King Mongkut's University of Technology Thonburi, Bangkok, Thailand
[c] Department of Civil Engineering, Faculty of Engineering, Prince of Songkhla University, Songkhla, Thailand

HIGHLIGHTS

- High unburned carbon and alkalis ashes have a potential to be raw materials in AAC.
- Fine particles and alkalis presented in residues are beneficial for strength gain.
- Strength and microstructure of AAC are affected by temperatures and times.
- The presence of alkalis in residues could stabilize the tobermorite in plate form.

ARTICLE INFO

Article history:
Received 25 November 2017
Received in revised form 28 March 2018
Accepted 4 April 2018

Keywords:
Black rice husk ash
Bagasse ash
Autoclaved
Aerated concrete

ABSTRACT

Both agriculture wastes, black rice husk ash (BRHA) and bagasse ash (BA), were used as sand replacement to prepare autoclaved aerated concrete (AAC) product at various temperatures and times. The compressive strengths of AAC were increased with the further autoclaving temperatures and times, except dry density. BRHA and BA have influence on the mechanical properties of AAC with low dry density for all conditions, approximately 6–54%, due to the high Na_2O and K_2O content and the fineness of both ashes compared to sand. The appearance of relative high Al_2O_3 of BA compared to BRHA leads to the additional strength gain of AAC sample containing BA, because of the formation of tobermorite through katoite. Therefore, both residues are shown to be highly potential substitution materials for sand in AAC production.

1. Introduction

Agriculture is known as a major sector in Thailand and the values from exporting are very successful internationally. The top three crops that have given the highest exporting values are rice, sugarcane and cassava [1]. Among these crops, the by-products from rice and sugarcane are usually utilized as fuel for boilers, consequently the solid residues or ashes that remain contain high unburned carbon and alkali components (Na_2O and K_2O) [2–4]. In current years, these ashes (rice husk ash and bagasse ash) have been widely demonstrated as pozzolanic materials, which have been normally used as an inert filler or cement replacement material [5–9]. Previous studies recommended that such residues contributed to concrete strength and durability [10–12], including alkali silica reaction (ASR) [13,14], and sulfate and chloride attack mitigation [15,16]. Also, both wastes were investigated for their use an absorbent [17,18], in glass-ceramic materials production [19], geopolymer [20,21], clay brick [22,23] and zeolite production [24].

Nowadays, autoclave aerated concrete (AAC) has received an increase interest due to its physical and mechanical properties. The benefits of AAC over traditional concrete are low weight, thermal and sound insulation, excellent fire resistance as well as being environmental friendly. The most common process of AAC is produced by introducing air voids into the matrix of concrete using the air-entraining agent (aluminium powder) subsequent to the hydrothermal process [25,26]. Si ions released from the siliceous materials during the hydrothermal process can react with amorphous calcium silicate hydrate (CSH) to form well-crystalline CSH or 1.1 tobermorite [27,28]. Several kinds of

* Corresponding authors.
E-mail addresses: kunchariyakun.k@gmail.com (K. Kunchariyakun), suwimol.asa@kmutt.ac.th (S. Asavapisit).

https://doi.org/10.1016/j.conbuildmat.2018.04.043
0950-0618/

industrial by-products, such as air-cooled slag, silica fume, fly ash, coal bottom ash, zeolite and rice husk ash have been used in AAC production. A previous study showed that the replacement of sand by air-cooled slag prepared using low-lime mixes could induce a tobermorite crystalline greater than high-lime mixes under hydrothermal conditions [29]. The utilization of coal bottom ash in AAC was reported to enhance the compressive strength with low unit weight [30]. While, the use of rice husk ash (RHA) as high reactive silica had a positive effect on autoclaving time and temperature [31]. Several research studies have indicated that the incorporation of industrial by-products in AAC production not only improves the properties of AAC but also reduces the wastes dumped into the environment by means of natural resource conservation practices.

However, very few research studies have been on the mechanisms of black color ashes containing high unburned carbon and alkali especially Na_2O and K_2O on the properties of AAC under different autoclaving temperatures and times. Thus, this research focuses on the use of two types of black color ashes namely, black rice husk ash (BRHA) and bagasse ash (BA). BRHA and BA are generated from the use of rice husk and bagasse as fuels in the boilers of rice milling plants and the sugar industry, respectively. Both ashes were used to replace sand at various proportions due to their high silica contents. The properties of AAC incorporating BRHA and BA, including compressive strength, dry density, water absorption and microstructure were investigated.

2. Materials and methodology

2.1. Materials

Ordinary Portland cement (OPC), sand (S), lime (L), black rice husk ash (BRHA), bagasse ash (BA) and aluminium powder were used as raw materials for the preparation of AAC samples. BRHA and BA were obtained from Chai Wanich Rice Mill and Ban Pong Sugar Industry, respectively. Both solid residues were firstly dried in an electric oven at a temperature of 105 ± 5 °C for 24 h, and then were ground in a ball mill to retain on sieve No. 325 under 34% by weight in accordance with ASTM C618 [32]. Ground residues were examined for the crystalline phases using X-ray diffraction (XRD; Miniflex using Cu Kα radiation (lλ = 1.5406 Å) at a voltage of 40 kV and 40 mA). In addition, sand was ground to an average particle size of approximately 100 μm. Aluminium powder was obtained from HiMedia Laboratories. The physical and chemical characteristics of raw materials used in this study are presented in Table 1. Chemical compositions were carried out by X-ray fluorescence (XRF; WDXRF PW2400) technique. The particle size distribution of ground sand, BRHA and BA (Fig. 1) were determined using Lazer particle size distribution (Malvern Mastersiser S Particle Size Analyser).

2.2. Experimental program

The mix proportions used in this study are given in Table 2. BRHA and BA were used as sand replacement at the level of 0, 30 and 50% by weight. Water/Binder (W/B) ratios were determined using the Flow Table method following ASTM C230/C230M [33]. Aluminium powder was added at the level of 0.7% by weight of binder. Solid components, i.e. OPC, lime, sand, BRHA, BA and aluminium powder, were mixed in a Hobart Mixer for 1 min, after that water was poured in and mixed again for 1 min and 30 s. The slurry was transferred into a 5 × 5 × 5 cm^3 steel mould and then was placed in an oven at a temperature of 40 °C for 3 h to achieve the desired setting and volume stability. The samples were then removed from the steel mould and were placed into the autoclave.

Table 1
Chemical and Physical Characteristics of Raw Materials.

Parameters	OPC	BA	BRHA	Quick lime	River sand
CaO	66.20	7.85	0.92	94.7	–
SiO_2	21.11	68.60	93.70	0.89	–
Al_2O_3	4.65	3.97	0.40	0.11	–
Na_2O	0.20	1.07	0.03	–	–
Fe_2O	3.22	3.16	0.28	0.10	–
MgO	0.79	1.69	–	2.61	–
P_2O_5	0.07	1.71	–	0.02	–
K_2O	0.75	3.92	2.55	0.01	–
TiO_2	–	0.27	0.02	2.34	–
MnO	–	0.14	–	–	–
SO_3	3.01	1.44	0.40	–	–
Cl^-	–	0.95	–	–	–
LOI (%)	1.69	5.22	4.40	–	–
Specific Gravity	3.14	2.35	2.13	2.34	2.58
Retained on Sieve No. 325 (%)	14	21.8	24.1	–	–
Average Particle (μm)	–	21.81	23.73	–	76.70

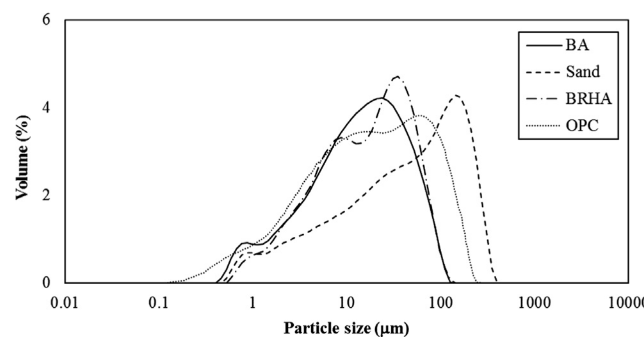

Fig. 1. Particle size distribution of sand, BRHA, BA and OPC.

Table 2
Mix proportions of AAC samples for 1 m^3.

Samples	Mix proportion (kg)						
	OPC	Lime	Sand	BRHA	BA	Al powder	Water
Control	649	72	721	–	–	5	483
A30	649	72	490	–	210	5	527
A50	649	72	344	–	344	5	620
R30	649	72	475	203	–	5	519
R50	649	72	326	326	–	5	579

The samples were cured in an autoclave under various temperatures of 140, 160 and 180 °C for 4, 8 and 12 h. The physical appearances of AAC samples containing BA and BRHA at 30 and 50% replacement for sand are shown in Fig. 2.

After autoclave curing, a set of five samples used for compressive strength test was dried at 40 °C for 24 h to contain 5–15% moisture content by mass (ASTM C1693) [34]. The other samples (a set of five samples) were dried at 105 ± 5 °C for 24 h to determine the dry density. After the compressive strength test, samples of the CT, A30 and R30 autoclaved at 140 and 180 °C for 4 and 12 h were chosen to be investigated for microstructure. The pieces of cracked samples were soaked in acetone solution to remove the remaining mixing water. Scanning electron microscopy (SEM, JEOL-JSM-6400) and XRD were used to examine the microstructure of AAC. For SEM analysis, the dried cracked samples were coated with gold. The samples for XRD were ground into a powder and examined with a step size of 0.02°, scan rate of 3° per min, and scan range of 10°–60° 2θ.