Construction and Building Materials 94 (2015) 807–816

Contents lists available at ScienceDirect

Construction and Building Materials

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

Unit weight, strength and microstructure of a water treatment sludge–fly ash lightweight cellular geopolymer

Cherdsak Suksiripattanapong [a], Suksun Horpibulsuk [b,*], Surachet Boongrasan [c], Artit Udomchai [b], Avirut Chinkulkijniwat [b], Arul Arulrajah [d]

[a] School of Civil Engineering, Faculty of Engineering and Architecture, Rajamangala University of Technology Suvarnabhumi Suphan Buri Campus, 450 Moo 6 Suphan Buri-Chainat Road, Sam Chuk District, Suphan Buri 72130, Thailand
[b] School of Civil Engineering, Suranaree University of Technology, 111 University Avenue, Muang District, Nakhon Ratchasima 30000, Thailand
[c] Graduate Program in Construction and Infrastructure Management, Suranaree University of Technology, 111 University Avenue, Muang District, Nakhon Ratchasima 30000, Thailand
[d] Swinburne University of Technology, Hawthorn, VIC 3122, Australia

HIGHLIGHTS

- A green lightweight cellular geopolymer from water treatment sludge.
- Unit weight, strength and microstructure of WTS–FA LCG.
- Role of liquid alkaline activator on material properties.
- Role of heat duration curing time on material properties.
- Optimum ingredient for manufacturing WTS–FA LCG.

ARTICLE INFO

Article history:
Received 10 April 2015
Received in revised form 3 June 2015
Accepted 14 July 2015
Available online 21 July 2015

Keywords:
Lightweight
Water treatment sludge
Fly ash
Geopolymer
Unit weight
Strength
Microstructure

ABSTRACT

A water treatment sludge–fly ash lightweight cellular geopolymer (WTS–FA LCG) is investigated in this research with the intention to develop an alternative green construction and building material, without using Portland cement as a cementing agent. Two waste by-products: WTS from the Bang Khen water treatment plants of the Metropolitan Water Work Authority of Thailand (MWA) and FA from the Mae Moh power plants of the Electricity Generating Authority of Thailand (EGAT) were used as an aggregate and a precursor, respectively. The liquid alkaline activator (L) used was a mixture of sodium silicate solution (Na_2SiO_3) and sodium hydroxide solution (NaOH). The unit weight and strength of WTS–FA LCG heated at 65 °C for various influential factors are investigated and presented in this paper. The various influential factors studied include mixing ingredient (air content (A_c), liquid alkaline activator content (L) and Na_2SiO_3/NaOH), heat duration and curing time. Scanning electron microscopy (SEM) analysis was undertaken to investigate the role of influential factors on unit weight and strength. The test results indicate that the L content at liquid limit state (LL) is optimal for manufacturing WTS–FA LCG for all Na_2SiO_3/NaOH ratios, heat durations and air contents tested for which the highest strength is attained. Although the unit weight of WTS–FA LCG significantly reduces when L > LL, it is not economical to manufacture WTS–FA LCG at L > LL due to the drastic strength reduction. The addition of A_c at L = LL is found to be an appropriate means to reduce the unit weight and minimize the strength reduction. The maximum strengths at L = LL for various air contents are found at Na_2SiO_3/NaOH of 80:20 and heat duration of 72 h. The longer heat durations of 96 and 120 h cause the loss of moisture, thereby resulting in micro-cracks and strength reduction. The WTS was found to be viable alternative aggregate to develop WTS–FA LCG, thereby resulting in this waste material traditionally destined for landfills to be used sustainably as a valuable resource.

© 2015 Elsevier Ltd. All rights reserved.

* Corresponding author.
E-mail addresses: cherdsak_2526@hotmail.com (C. Suksiripattanapong), suksun@g.sut.ac.th, suksun@sut.ac.th (S. Horpibulsuk), avirut@sut.ac.th (A. Chinkulkijniwat).

http://dx.doi.org/10.1016/j.conbuildmat.2015.07.091
0950-0618/© 2015 Elsevier Ltd. All rights reserved.

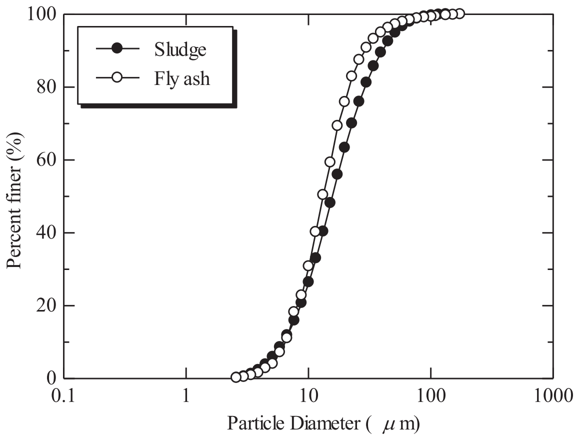


Fig. 1. Grain size distribution of WTS and FA.

Table 1
Chemical composition of sludge and fly ash.

Chemical composition (%)	Sludge	Fly ash
SiO_2	67.33	47.51
Al_2O_3	22.47	13.14
Fe_2O_3	6.15	6.66
CaO	0.68	30.24
MgO	N.D.	N.D.
SO_3	1.04	N.D.
Na_2O	N.D.	0.41
K_2O	1.26	1.63
LOI	0.78	0.42

Note: N.D. = not detected.

1. Introduction

The increasing demand of treated water in water treatment plants worldwide, has resulted in increasing quantities of sludge by-products generated annually. For the Metropolitan Waterworks Authority of Thailand (MWA), water treatment sludge (WTS) is generated at the maximum capacity of 300 tons per day in the dry season and increasing to 700 tons per day in the wet season [1]. Quantities of WTS is increasing annually in metropolitan areas due to the ever increasing water demands of a rapidly growing population, subsequently resulting in the need for increased landfill space to dispose this waste by-product.

The usage of recycled waste materials [2–21] in civil engineering applications such as embankment fills, pipe-bedding and pavement base/subbase has grained rapid traction in both developed and developing countries alike. Similarly, MWA has recently researched on the possible usage of WTS as construction and building materials according to a zero-waste directive. It is found that the WTS could be used as an aggregate to manufacture sustainable geopolymer bearing units [22,23].

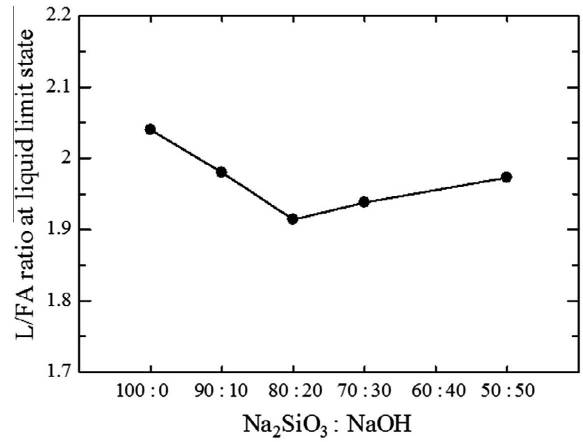
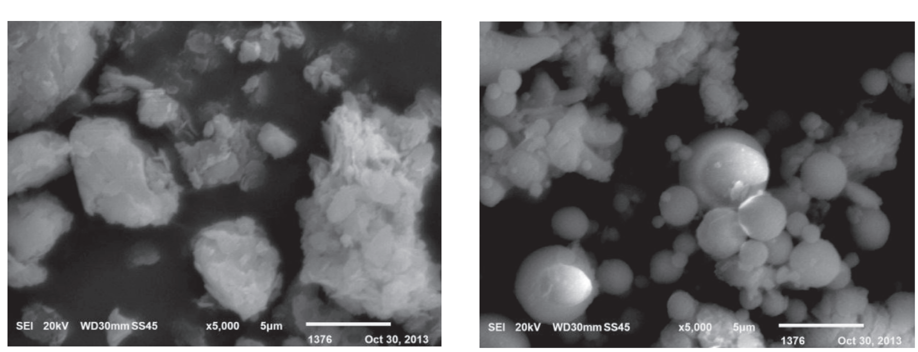


Fig. 3. Relationship between L/FA ratio and Na_2SiO_3/NaOH ratio.

Geopolymers are touted for their high performance (high strength and durability), low CO_2 emission and low energy consumption. Geopolymers have become increasingly popular in recent years as an environmental-friendly alternative to ordinary Portland cement [24]. Silica and alumina rich materials such as clay or kaolin [25], fly ash, and bottom ash [26] can be used as a precursor to react with the liquid alkaline activator. Fly ash (FA) derived from coal-fired electricity generation provides the greatest opportunity for commercial utilization of this technology due to the plentiful worldwide raw material supply [27,28]. FA is extensively used as a precursor for geopolymers in Australia [29,30] and Thailand [31–33].

The usage of a natural silty soil as an aggregate to manufacture sustainable geopolymer masonry units has been pioneered by Sukmak et al. [34–36]. It was reported that the 7-day strength of the soil-FA geopolymer is greater than 10 MPa, deeming it suitable as a bearing masonry unit. The durability against sulfate attack of soil-FA geopolymer is superior to that of clay-cement; i.e., there is no major change in the microstructure and pH of soil-FA geopolymer when exposed to sulfate solutions.

Recently, Suksiripattanapong et al. [22] investigated the strength development in WTS–FA geopolymer as a bearing masonry unit. The NaOH and Na_2SiO_3 were used as a liquid alkaline activator while high calcium fly ash was used as a precursor. The optimum ingredient providing maximum unit weight and strength is NaOH/Na_2SiO_3 ratio of 80:20 and L/FA ratio of 1.3, irrespective of heat condition and curing time. The optimum heat temperature and duration for the optimum ingredient are 75 °C and 72 h,



(a) sludge (b) FA

Fig. 2. SEM images of WTS and FA.

Download English Version:

https://daneshyari.com/en/article/6720755

Download Persian Version:

https://daneshyari.com/article/6720755

Daneshyari.com