Influence of Bagasse Ash as Fine Aggregate on the Property of Cellular Concrete

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Abstract

This research focuses on influence of utilizing original bagasse ash as fine aggregate on the property of cellular concrete. The original bagasse ash (BG) from the Thai sugar industry was used to replace river sand (SA) at 0%, 20%, 30% and 40% by volume. All mixes were controlled flow between 45 ± 5% and used foam content (FV) at 50% by volume of mixture. Compressive strength, density, water absorption, and microstructure analysis were determined. The results revealed that the compressive strength and density decreased with increasing of BG content, while the water absorption slightly increased as compared to the control cellular concrete. In addition, it was found that the increasing of the BG content had a little effect on the chemical reaction of cellular concrete. The optimum replacement level of BG to SA was 20% by volume which it gave the compressive strength, density, and water absorption of 3.37 MPa, 1,000 kg/m^3 and 25%, respectively. From the experimental results, it can be concluded that the BG could be used as a fine aggregate in the cellular concrete.

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Keywords : Cellular concrete, bagasse ash, Compressive strength, water absorption.

1. Introduction

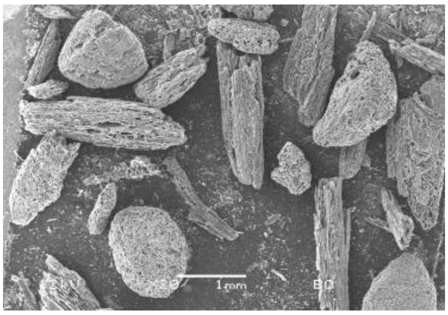
In recent years, cellular concrete has increasingly been used in construction because it has an advantage of reducing the sizes of structure [1]. Generally, cellular concrete can be classified into two types: autoclave and non-autoclave cellular concrete. High-pressure steam curing makes the autoclave cellular concrete to improve the quality in lighter weight, low thermal conductivity, high heat resistance, and low drying shrinkage as compared to the non-autoclave cellular concrete [2]. However, non-autoclave cellular concrete has lower expense than autoclave.

In Thailand, bagasse ash (BG) is a by-product from the Thai sugar industry. It is estimated that more than 200,000 tons of BG are produced every year [3], and this increases annually. Most studies of BG focus on the pozzolanic activity and hydration reaction of mortar. Some study has been carried out regarding the usage of BG in concrete as sand replacement [4]. However, a little of the BG is actually used, while the most of BG is disposed in landfills. Then, the purpose of this research was to investigate on influence of utilizing original BG as fine aggregate in non-autoclaved cellular concrete due to several advantages, for example lower costs, reduction in the use of natural resources, waste disposal, prevention of environmental pollution and energy savings. Additionally, the high porous characteristics of BG particles may reduce the shrinkage of cellular concrete as same as using lightweight aggregate in foam concrete which was observed by Regan [5]. Moreover, this research may conform to Thailand 4.0 policy of the government, under the vision of “Stability, Prosperity, and Sustainability”. As development of creativity, innovation, science, technology, and research are needed in order to fully activate Thailand 4.0.

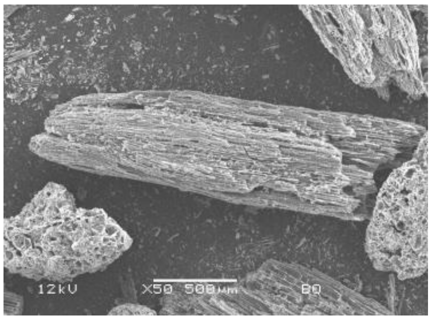
2. Experimental program

2.1 Constituent materials and mix proportion

The materials used in this study consist of i) ordinary Portland cement (OPC) conforming to ASTM C150, ii) river sand (SA, specific gravity of 2.56), iii) original BG from the Thai sugar industry (Specific gravity of 1.93) which shows particles shapes in Fig.1., and iv) foam that produced by aerating an organic based foaming agent (dilution ratio 1:30 by volume) using an indigenously fabricated foam generator to a density of 50 $\mathrm{kg/m^3}$. The Physical and chemical properties of materials used in this study are presented in Table 1.



(a)



(b)

Figure 1 SEM of original BG: the observed at magnification 20x (a) and 50 x (b)

The mix proportions of all cellular concrete mixes reported are given in Table 2. Different mixes of cellular concrete were made by using of foam content (FV) at 50% by volume of mixture, and used BG to replace SA at the rates of 0, 20, 30 and 40% by volume of sand and keeping the filler–cement ratio at 1 by weight.

Table 1 The physical and chemical propertie of materials

Physical properties	OPC	SA	BG
Specific gravity	3.14	2.56	1.93
Absorption (%)	-	1.21	32.8
Voids (%)	-	34.6	80.4
Fineness modulus	-	2.76	1.12
Blaine (cm^2/g)	3,270	-	-

Table 1 The physical and chemical properties of materials

Physical properties	OPC	SA	BG
Chemical composition (%)			
SiO_2	20.62	92.86	75.33
Al_2O_3	5.22	3.17	3.94
Fe_2O_3	3.10	0.27	3.87
CaO	65.00	0.55	2.40
MgO	0.91	0.49	3.70
K_2O	0.07	0.32	3.05
Na_2O	0.50	0.42	0.78
SO_3	2.70	0.55	0.88
LOI	1.13	0.67	13.59

Table 2. The mix proportions of cellular concrete

Mixture	Mix proportion (by volume)				
	OPC	SA	BG	FV	water
CC	0.127	0.155	0	0.5	0.218
20BG	0.120	0.124	0.031	0.5	0.225
30BG	0.117	0.108	0.047	0.5	0.228
40BG	0.114	0.093	0.062	0.5	0.231

2.2 Testing details

Based on several trails, the percent flows (consistency), measured by standard flow table in accordance with ASTM C 230 (without raising/ dropping of the flow table as it may affect the foam bubbles entrained in the mix) was arrived at 45 ± 5%. Earlier studies showed that within this range, it is the good stability and consistency [6]. After that, the specimens were removed from the mould after 24 h.

The compressive strength was measured by 50 mm cubes at the ages of 7 and 28 days in accordance with ASTM C 109. An average of the three values at each age was calculated.

Water absorption is usually measured by drying the specimen to constant mass, immersing it in water and measuring the increase in mass as a percentage of dry mass. Absorption were measured on three cube specimens of size 50 mm for each mix of cellular concrete which have been moist-cured at 28 days.

The morphology and microstructure analysis of cellular concrete were characterized using scanning electron microscope (SEM) images and electron X-ray (EDX) spectrum with 15 kV, respectively. Gold-coated samples were used to examine fracture surfaces.

3. Results and discussion

3.1 Compressive strength

Fig. 2 shows that the compressive strength of cellular concrete after 7 and 28 days of water curing. It is found that the cellular concrete made from 20BG present the highest compressive strength, while the replacement level of SA by BG more than 20% gives the compressive strength results lower than those of the control cellular concrete (CC) at all ages because increasing of water content and pore number in cellular concrete will induce a decrease of compressive strength. Similar results have been reported on a study of compressive strength of lightweight concrete in literature [7, 8].

3.2 Density

Fig.3 indicates that the increasing of BG content leads to decrease of density due to its low specific gravity (1.93) as compared to SA (2.56). The relationship between the compressive strength and density of cellular concrete is shown in Fig.4. It is found that the compressive strength at the age of 7 and 28 days decreases exponentially with a reduction in density of cellular concrete [9]. The following relation for strength and density of cellular concrete is fit well with R^2 values of 0.8791 and 0.8722 at the age of 7 and 28 days, respectively.

3.3 Water absorption

Fig.5. presents the effect of BG as sand replacement on water absorption at the age of 7 and 28 days. At the replacement the BG content increases, the water absorption increased due to the increased of capillary porosity in cellular concrete. Similar results have been reported on water absorption of foam concrete using fly ash as sand in literature of Kunhanandan and Ramamurthy [10].

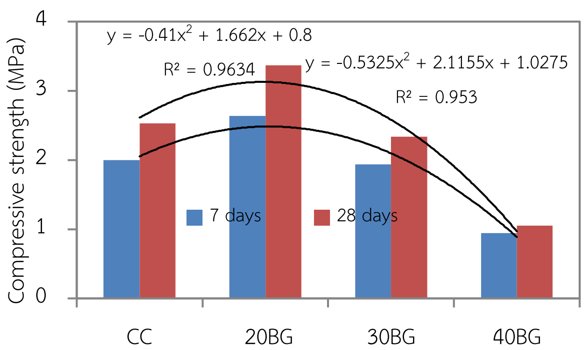


Figure 2 Compressive strength of cellular concrete

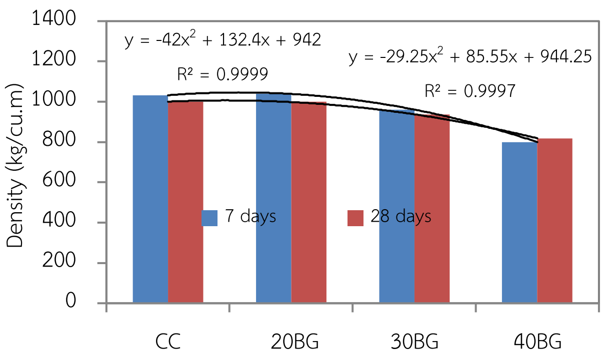


Figure 3 Density of cellular concrete

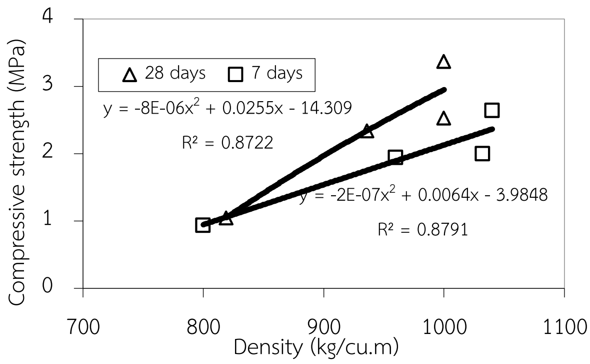


Figure 4 Relationship of compressive strength and density of cellular concrete

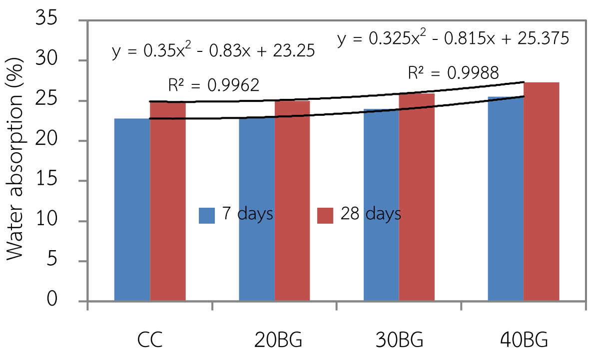


Figure 5 Water absorption of cellular concrete

With the current results, it could be concluded that 20% of the BG as SA replacement was the optimum of BG content due to the compressive strength and density of cellular concrete are equal to class 10 in accordance to Thai Industrial Standard (TIS) 2601. At the age of 28 days, the results of 20BG cellular concrete had the compressive strength, density, and water absorption of 133.20%, 100%, and 100.40% more than that of the control cellular concrete, respectively.

However, the water absorption of BG cellular concrete is greater than that of TIS standard. Although the water absorption obtained from cellular concrete containing 20BG is higher than for TIS standard, nevertheless, the water absorption of this research is lower than typical clay brick in Thailand' s Construction Industry. Furthermore, its compressive strength and density in this research meets most the required clay brick properties. These comparisons are summarized in Table 3.

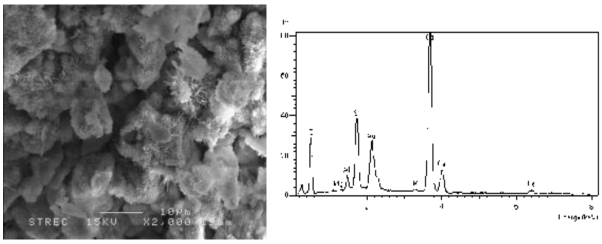
Table 3 Comparison between cellular concrete and other materials.

Description	Cs (Mpa)	Ds (kg/m^3)	Wa (%)
Optimum mix in this research	3.4	1000	25
Aerated Lightweight Concrete			
(TIS 2601-2013) class 8	2.0	701-800	25
(TIS 2601-2013) class 9	2.5	801-900	23
(TIS 2601-2013) class 10	2.5	901-1000	23
(TIS 2601-2013) class 12	2.0	1001-1200	23
(TIS 2601-2013) class 14	5.0	1201-1400	20
Commercial clay brick (in Thai)	2.0-3.0	1650	40

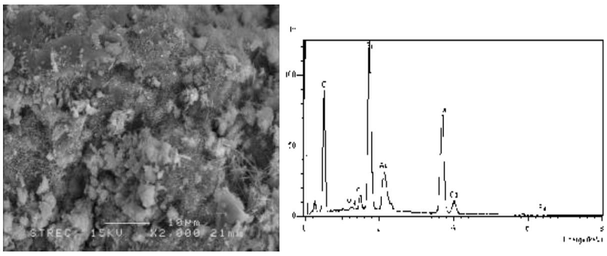
Cs=Strength, Ds=Density, and Wa=Water Absorption

3.4 Microstructure Analyses

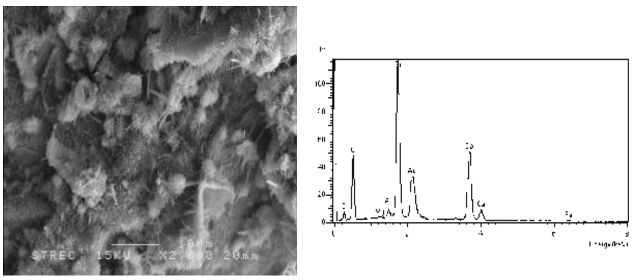
The typical SEM-EDX at magnitude of x2,000 of cellular concrete is shown in Figure 6. Figure 6(a) showed that the SEM image of CC (without BG) after 28 days and Figure 6(b)-6(d) showed that the SEM image of cellular concrete containing BG. At x2,000 of SEM, it can be seen that the microstructure morphology of fracture surface of cellular concrete was rough surface due to hydration production (CSH and ettringite). However, the 20BG had the denser surface than that of CC due to hydration reaction and packing effect. The results of the EDX analysis of cellular concrete confirm with the presence of Ca and Si as major elements. In addition, it was found that the increasing of the BG content had no significant effect on the chemical reaction of cellular concrete.



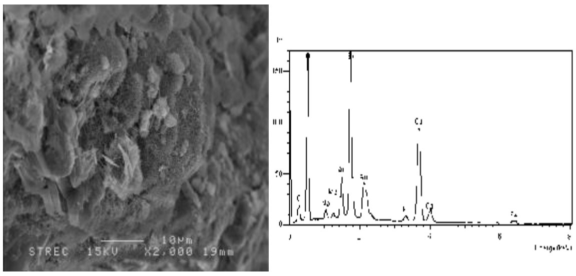
(a) CC



(b) 20BG



(c) 30BG



(d) 40BG

Figure 6 SEM image and EDX spectrum of cellular concrete after 28 days.

4. Conclusions

The experimental results on influence of utilizing BG from the Thai sugar industry, can be concluded as follows :

1. The cellular concrete made from 20% of BG results the highest value of compressive strength, while the BG percentage higher than 20% shows that the lower compressive strength as compared to the control cellular concrete.

2. The optimum replacement of BG in cellular concrete was 20% by volume of SA. It gaves compressive strength, density and water absorption at the age of 28 days of 3.37 MPa, 1,000 kg/m^3 and 25% , respectively. In addition, it was closed to class 10 of TIS standard. Moreover, the resultant properties of the optimum mix are greater than typical clay brick in Thailand's construction industry.

3. The EDX analysis results showed that the increasing of BG content had no significant effect on the chemical reaction of cellular concrete.

4. The results of this study suggested that BG could be applied as a fine aggregate in cellular concrete. Moreover, its shows positive results in terms of environmental protection, waste management practices, and saving of raw materials.

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