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Study on use the bottom ash from waste incineration plant as fine aggregate in manufacture of controlled low-strength materials

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KEYWORDS

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ABSTRACT

This research investigates the manufacture and properties of controlled low-strength materials (CLSM) that were produced using bottom ash (BA) as fine aggregate (F). Mixtures of CLSM were prepared with various volume ratios of F-to-BA (100/0, 90/10, 70/30, and 50/50) and a constant amount of 5% cement, 10% slag, 82% fly ash and 3% $CaCL_2$. CLSM mixtures were prepared at an initial ratio of water to powder (w/p) of 0.35 and added water to obtain the flow of 30±2cm. The properties of CLSM were evaluated by relevant standards. The experimental results show that the flow of all CLSM mixtures met high flowability requirements under ACI 229R. Using BA as fine aggregate reduced the fresh unit weight of CLSM but delayed the setting time. Moreover, CLSM mixtures could serve as a re-excavation and pavement subbase.

1. Introduction

Controlled low-strength materials (CLSM) are applied as backfills, structural fills, pavement bases, and void fills. As a definition of American Concrete Institute, maximum 28-day compressive strength of CLSM is limited to 8.3 mpa. The recent studies of CLSM made with different wastes have attracted the attention of researchers. Chau Truong Linh (Chau Truong Linh, 2018) has studied the use of a mixture of coal slag - untreated fly ash - cement as foundation material, subbase course in flexible pavement. The results of this investigation show that the mixture of materials meets the strength level II, III according to the standards TCVN 10379-2014 and TCVN 10186-2014 and may be used as the subbase for A1, A2 pavement or the fill material for embankment, with a cement content of 02% to 8%. Moreover, experimental results of Bui Tuan Anh and Tran Thi Kim Dung confirm the possibility of using untreated fly ash for road base/subbase construction (Bui Tuan Anh and Tran Thi Kim Dung, 2015). The study of Wen-Ten Kuo et al. Shows that replacing fine aggregate with oyster shell does not significantly affect compressive strength but reduces water absorption of CLSM material (Wen-Ten Kuo et al., 2013). Besides, Jinxi Zhang et al. (Jinxi Zhang et al., 2018) have studied CLSM materials using recycled fine aggregate from construction-demolition waste and accelerator. The results show that using 20-50% of the accelerator reduces the bleeding rate with no significant effect on the flowability. CLSM with a new type of slag replaced the natural aggregate presented the the setting time of 97–270 min, value of the ball drop of 46–61 mm and a reduction of 28-day compressive strength as the replacement increased (Her-Yung Wang and Kuo-Wei Chen, 2016). However, limited studies have focused on CLSM that was made with bottom ash from waste incineration plant.

This present work examines the properties of CLSM produced using the bottom ash from waste incineration plant as fine aggregate. CLSM is prepared with the ratio of powder and fine aggregate 50/50 at. A constant powder mixture consists of 5% cement, 10% slag, 82% fly ash and 3% calcium chloride $cacl_2$. BA is used to replace fine aggregate at the levels of 0%, 10%, 30% and 50% volume of aggregate. Furthermore, properties of CLSM such as the flow, fresh unit weight, setting time, ball drop and compressive strength are tested according to relevant standards.

2. Materials and experimental program

Cement PC40 of Nghi Son Company was used in this study. Class F fly ash (FA) collected from Dien Hai power plant, Tra Vinh province and ground blast furnace slag (S) S95 of Hoa Phat group were used as powder. cũng được sử dụng. The specific gravity of cement, FA, and S was 2,94, 2,13, và 2,86 g/cm^3, respectively. Chemical compositions of powders were analyzed by X-ray fluorescence (XRF) and shown Table 1.

River sand (RS) with a fine modulus, specific gravity and water absorption of 1.18, 2.62 g/cm^3, and 1.78 %, respectively, was obtained from a locally available source. Furthermore, BA with a fine modulus, specific gravity and water absorption of 2.28, 1.33 g/cm^3, and 40 %, respectively, selected from waste incineration plant at Co Do District, Can Tho City were used as fine aggregate. Fig. 1 and Fig 2.

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showed the appearance and the particle size distributions of the RS and BA, respectively. Moreover, the heavy metal content of BA is presented in Table 2. The experimental result showed that the leaching concentrations of BA satisfied the requirements of national Vietnamese technical regulation 07-2009/BTNMT of the Ministry of Natural Resources and Environment.

Table 1. Chemical compositions of cement, FA, and S.

Item	Cement	FA	S
SiO2, wt,%	22,45	58,75	38,01
Al2O3, wt,%	6,81	26,15	13,13
Fe2O3, wt,%	3,15	5,62	0,55
CaO, wt,%	60,03	2,03	36,8
MgO, wt,%	2,08	1,63	5,77
Others, wt,%	3.31	5,82	5,74

Table 2. Chemical compositions of cement, FA, and S.

Item	Unit	Content	07-2009/BTNMT
As	ppm	5.0	40
Cd	ppm	0.7	10
Pb	ppm	51.6	300
Zn	ppm	76.9	5000
Cr	ppm	0.9	100
Ni	ppm	5.2	1400
Hg	ppm	0.14	4
Co	ppm	22.6	1600

(a) (b)

Fig. 1. The appearance of materials: (a) bottom ash; (b) river sand.

The mix proportions of CLSM used in the study are given in Table 3. CLSM was made with the constant powder mixture of 5% cement, 10% S, 82% FA, and 3% CaCL2. Moreover, BA was used as fine aggregate to replace RS at the replacement levels of 0%, 10%, 30% and 50% by volume. The CLSM mixture is prepared at an initial ratio of water and powder of 0.35 and then water is added to the mixture so that the CLSM achieves the flowability required by the ACI committee 229R. A series of tests such as the flow, fresh unit weight, setting time, ball drop and compressive strength was done according to ASTM D6103, ASTM D6023, ASTM C403, ASTM D6024 and ASTM D4832, respectively.

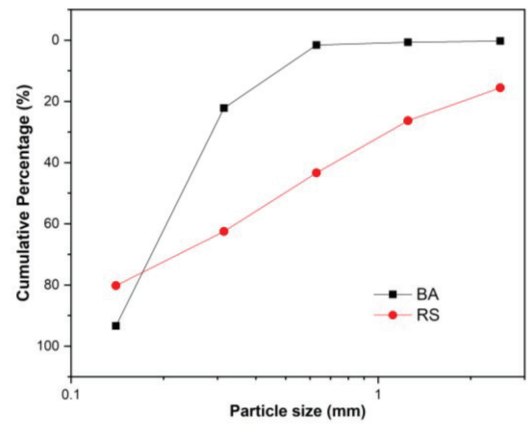

Fig. 2. The particle size distributions of the RS and BA.

Table 3. Mix proportions of CLSM (kg/m^3).

Mix	PC	FA	S	$CaCL_2$	Water	RS	BA
C	43	710	79	26	300	857	0
B10	43	710	79	26	300	772	44
B30	43	710	79	26	300	600	131
B50	43	710	79	26	300	429	218

3. Results and discussions

3.1. Flow and fresh unit weight

The flow and fresh unit weight of CLSM mixtures is illustrated in Fig. 3. All mixtures of CLSM were added with water to achieve the required flow of 30±2cm. As expected, the flow of all CLSM mixtures exceeded 20cm, satisfying the minimum requirements of high flowability in accordance with ACI 229R. Additionally, the experimental results showed that lower fresh unit weight of CLSM mixture was associated with higher levels of BA content. For example, fresh unit weight decreased from 2026 to 1926 kg/m3 as substitution volume of BA increased from 0 to 50 %. This issue is due to the low specific gravity of BA compared to RS.

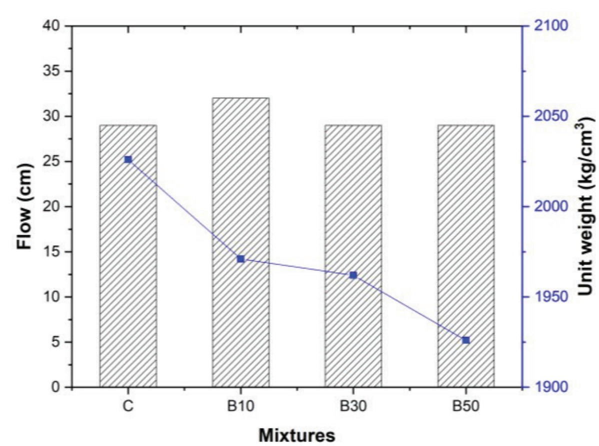

Fig. 3. The flow and fresh unit weight of CLSM mixtures.

3.2. Setting time and ball drop

Wen-Ten Kuo et al. recommended that the setting time of general CLSM varied from 12 to 36 hours (Wen-Ten Kuo et al., 2013). The setting time is determined as the elapsed time from the beginning of the mixing until the time when a penetration resistance of 3.5 MPa is recorded under ASTM C403.

The setting time of CLSM mixtures is presented in Fig. 4. As expected the setting time increased with BA dosage. The elapsed time of CLSM mixtures that were made with BA contents of 0%, 10%, 30%, and 50% by volume of fine aggregate was 15.5, 21.4, 25.9, and 30.1 hours, respectively. The higher water absorption of BA led to the greater free water of CLSM mixture is the key reason for the increase of setting time. However, all mixtures of CLSM met the allowable elapsed time compliance with the requirement as previously discussed.

Fig. 4 describes the value of the ball drop of various replacements of BA. The indentation diameter of CLSM mixture varied from 9 to 10.5 cm. These mixtures are suitable for application of pavement subbase according to ASTM D6024.

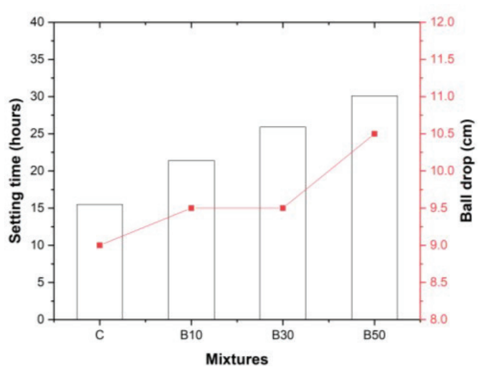

Fig. 4. The result of setting time and ball drop.

3.3. Compressive strength

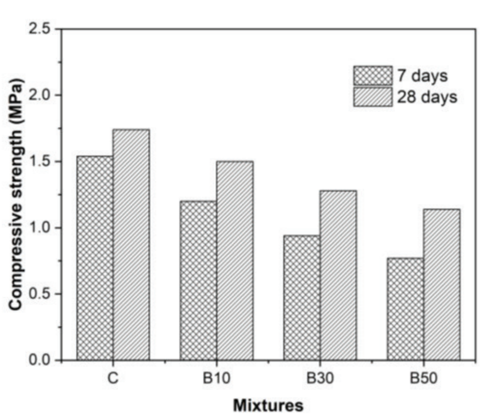

Fig. 5. The compressive strength of different CLSM mixtures at 7-day and 28-day curing ages.

Fig. 5 shows the compressive strength of CLSM at 7 days and 28 days of curing. Using more BA content resulted in lower compressive strength. Furthermore, the compressive strength value of the CLSM increased with specimen age. The 7-day and 28-day compressive strength reduced from 1.54 to 0.77 MPa and from 1.74 to 1.14 MPa, respectively, as the replacement rate of BA increased from 0 to 50%. This issue may be due to an increase of voids in CLSM samples which used BA to replace RS. The compressive strengths of all mixtures of CLSM determined complied with the strength requirement of re-excavation, which is less than 2.1 MPa.

4. Conclusions

Based on the experimental results described in this paper, the following conclusions may be drawn:

- The flow of all CLSM mixtures met high flowability requirements under ACI 229R. Moreover, fresh unit weight reduced from 2026 to 1926 kg/m^3.
- The setting time was delayed with the replacement of BA. However, The value of ball drop increased with this replacement.
- The compressive strengths of all CLSM mixtures are measured satisfying the requirement of the strength of re-excavation under ACI 229R.

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