Trench Backfill Material Using Plant Coal Ash

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ABSTRACT

This study investigates the applicability of ponded ash as backfill materials using air foam technology. The objective of this study is to recycle as much as ponded ash with a small amount of cement quantity. Various ponded ash contents as the replacement for different cement-ponded ash mixtures were used to evaluate applicability as backfill materials. The fresh and hardened properties of all combinations were determined by conducting flowability, setting time, unconfined compressive strength (UCS) test. Also, leaching test and salt concentration analysis were performed to evaluate the availability of ponded ash as backfill materials. The test results showed that cement-ponded ash mixture with air foam could be used as backfill materials in terms of mechanical and environmental properties.

INTRODUCTION

In recent years, there have been significant efforts in utilizing various industrial by-products in the production of many construction materials. With the subject of by-product development, several promising studies have been published such as the application of bauxite red mud in self-compacting concrete [9], utilization of fly ash cement concrete in the construction of road, development of self-leveling concrete using high amount of fly ash [10]. However, there are still various by-product materials that have yet to be researched because of their low-quality characteristic and hazardous components. Due to a huge consumption of energy in the industrial revolution, million tonnes of coal ash have been generated from power plants every year. In wet ash disposal system, the combination of fly ash (FA) from the precipitators and the bottom ash (BA) from the boilers are transported in the slurry form into the disposal site, where water is drained off or recycled. This mix is defined as ponded ash which is classified as a waste by-product material [4]. In fact, ponded ash is mostly not recycled as FA but stored in wetted reclamation site. If this by-product material is not properly controlled, there will be many problems due to the shortage of waste storage, causing serious impact to the environment. Accordingly, utilizing ponded ash as diverse construction materials and minimizing the demand on landfill will contribute towards the sustainable development [6]. This has led to the potential concern of identifying the new method for the application of ponded ash.

This study presents the experimental investigation in the new development of air foam backfill materials using ponded ash. Several mixtures were tested to evaluate the combined use of ponded ash and construction sand in backfill materials manufacture, 4 different ratios of sand (S) and ponded ash (PA) content were made as fine aggregate: (100% S – 0% PA, 70%S – 30%PA, 40%S – 60%PA, 0%S – 100%PA). There are 3 conditions of cement contents (30 kg/m^3, 60 kg/m^3, 90 kg/m^3) and 2 conditions of air foam (15 and 20 %). In this research, there are three main stages which were conducted to analyze the applicability of ponded ash as backfill materials. In stage 1, optimum mix proportion was figured out by flowability and setting time test. Stage 2 focused on hardened properties that were monitored for 28 and 90 days unconfined compressive strength. Final stage investigates the environmentally friendly property of ponded ash based backfill material following leaching test and salt concentration analysis.

MATERIAL

Portland cement type I was used in this study. Ponded ash was obtained from the reclamation site operated by Korea Western Power Plant Corporation, Korea. The ponded ash contained different size from fine powder to nearly 10mm. The grading curve for ponded ash is shown in Figure 1. Foaming agent was used to produce air foam in this study. After mixing it with water, it can be foamed and expand up to 25 times in volume into air-foam by the compressor. Adding air foam to mixtures will provide lightweight which is greatly beneficial where weak soil conditions are encountered and the weight of the filling material must be kept at low level. The including of air foam provides the flowability, minimal bleeding, segregation. The characteristics of the materials used in this research are shown in Table 1.

Table 1. Material properties

Material	Description
Portland cement	ASTM C150 Type I (Specific gravity = 3.15 g/cm^3)
Ponded ash	Specific gravity = 2.1 g/cm^3, moisture content: 22%
Construction sand	Specific gravity = 2.6 g/cm^3, moisture content: 7%
Air-foam agent	Specific gravity = 1.03 g/cm^3, pH = 7.1

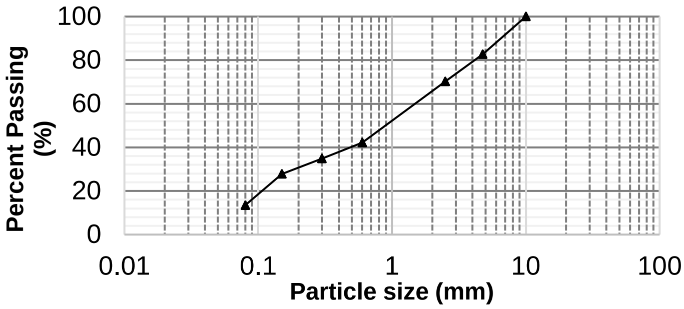

Figure 1. Grading curve of Ponded Ash

Mix proportion

The mix formulation used in this study are described in Table 2. In this study, water-to-solid ratio (w/s) was controlled at approximately 0.22 as a minimum ratio based on preliminary studies and trial experiments. Regards to the mixing process, fine aggregate, ponded ash, and cement were first mixed with about half of the required water content for 2 minutes, followed by 1 minutes of the rest period to ensure a thorough mixing. Thereafter, the remaining water and prepared air foam were added and mixed again for another 3 minutes [11]. Following the mixing stage, the slurry was then cast into specimens in the PVC pipe molds which have 150mm in height and 150mm in diameter for the penetration test. The same method was carried out for both flow test and unconfined compressive test, but the molds were 140-mm height and 70-mm diameter.

Table 2. 15% air foam mix formulations.

Mix	**Cement**	**Ponded ash**	**Sand**	**Air foam**	**Water**
	Kg/m^3	Kg/m^3	Kg/m^3	L	Kg/m^3
0PA30a	30	0	1577	150	212
0PA60a	60	0	1536	150	200
0PA90a	90	0	1527	150	162
30PA30a	30	446	1041	150	170
30PA60a	60	439	1025	150	156
30PA90a	90	426	994	150	127
60PA30a	30	850	566	150	135
60PA60a	60	834	556	150	118
60PA90a	90	817	544	150	90
100PA30a	30	1358	0	150	30
100PA60a	60	1292	0	150	60
100PA90a	90	1226	0	150	90

*0PA30a = 0% Ponded ash - 100% sand, $30kg/m^3$ cement and 15% air foam

LABORATORY TESTING

Flowability

In this research, the flow test was conducted in accordance with ASTM D6103. After thorough mixing, the paste was filled to a 70 (diameter) x 140mm (height) open-ended cylinder held firmly in steel plate. Then, the cylinder was raised up vertically and gradually in 3 seconds and the largest spread diameter was measured. The initial mixture proportion was kept if the sample spread diameter is between 200 and 250mm with no sign of segregation. If the diameter was less than 200mm, more water was added until reaching the desirable flowability. The amount of added water was then recorded to modify the final mixture proportion. If the diameter excessed 300mm, the initial formulation was calculated

As can be seen from Figure 2a, the initial flow test results varied from 175mm to 430mm. The result indicated that the workability of backfill material mixture was influenced significantly by the fine aggregate proportion. Those mixtures of 100% sand showed relatively low flow value (ranging from 183 to 211 mm). Hence, more water was added to achieve optimum flowability in mixtures with higher sand quantity. In the other hand, higher ponded ash content led to the higher the flowability level of the mixture. Regards to the flowability of final mixtures, final formulations were set up and they almost all showed perfect flowability (ranging from 211 to 259mm) due to the benefit from the initial test. (Fig. 2b).

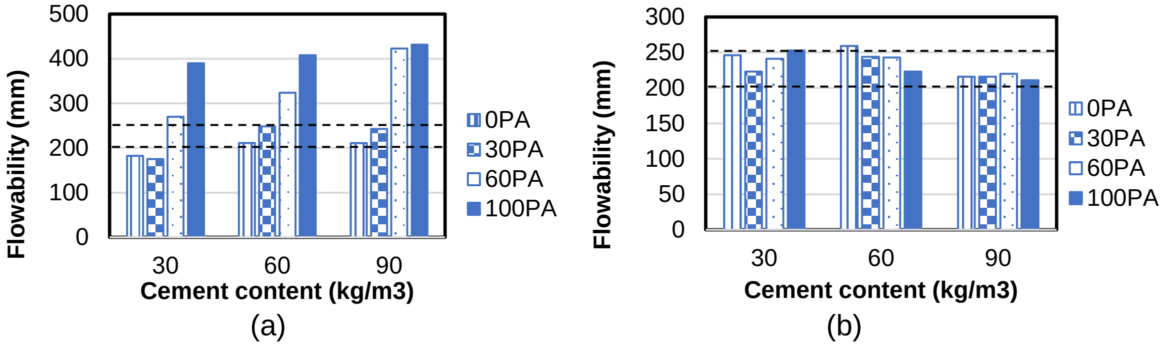

Figure 2. Flow test results specimens at 15% air foam: (a) in the trial mixtures, (b) in final mixtures.

Setting Time

Needle penetration was used to measure the hardening process of backfill material in accordance with ASTM C403. The test was performed after 4 - 5 hours after the first contact between cement and water. The depth of penetration was 25mm. As determined in related researches, the time required for the samples to reach 2.74 MPa of resistance to penetration was used to define the time of setting [8].

Figure 3 demonstrates the setting time of all backfill material mixtures, varied from 13 to 93 hours. The mixture with 90 kg/m^3 cement and 100% ponded ash had the fastest setting time within 13 hours. The higher cement content was added the faster target setting time was achieved. Therefore, more cement can be added to prevent a long setting time. The setting time of samples was also reduced by the enhancement of ponded ash content. For a constant cement content of 60 kg/m^3, the setting time decrease from 84 to 18 hours when ponded ash content increased from 0 to 100%.

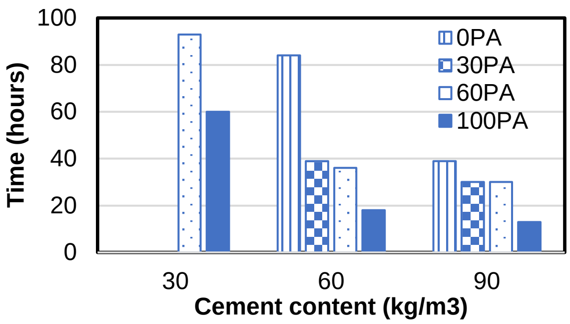

Figure 3. Penetration test result of backfill material mixtures at 15% air foam

Unconfined compressive strength

The unconfined compressive strength test was conformed to ASTM D4832. Regarding curing condition, after 7 days of 100% moist-curing in room temperature at 23°C, all the specimens were demolded and carefully stored in the same curing condition until the test day. Testing machine capacity was 50kN and loading rate was kept low at 1 mm/min. All dimensions of specimens were measured and the test was conducted. Each strength test was done on three cylinders and the average values were obtained. The unconfined compressive strength data of cylindrical specimens tested at 28 and 90 days are presented in Figure 4 and 5. Group specimens with 90 kg/m^3 cement content accounted for the highest compressive strength. The increase in strength was more pronounced when more sand was replaced by ponded ash. In terms of air foam content, the samples with 15 % air foam acquired higher strength than the ones with 20 % air foam. It demonstrated that the higher level of air foam will strongly lead to the drop of unconfined compressive strength of samples (Fig. 4). After 90 days of curing in the same conditions, almost all samples exhibited a small increase in strength compare to 28 days-result (Fig. 5). Especially, the combinations of 15% air foam, 100% ponded ash, and cement content ranging from 60 to 90 kg/m^3 fulfilled this study target strength which is from 0.5 to 1 MPa and lower than 1.4 MPa in 28-day and 90-day UCS respectively.

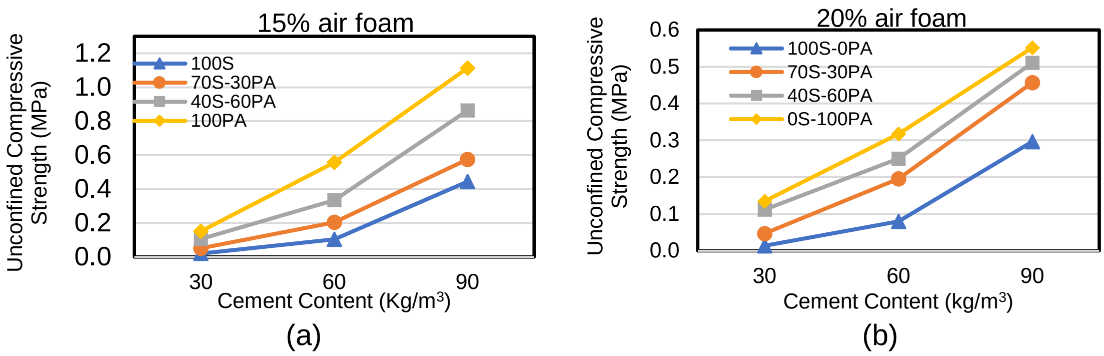

Figure 4. The effect of cement content and ponded ash to the 28-day unconfined compressive strength at: (a) 15% air foam and (b) 20% air foam.

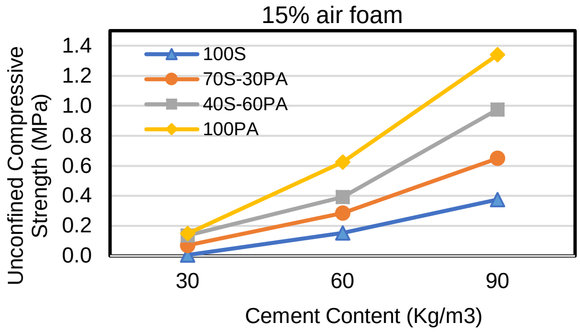

Figure 5. The effect of cement and ponded ash content to the 90-day UCS at 15% air foam.

CONCLUSIONS

This paper discussed the viability of using ponded ash in the production of backfill materials. The following conclusions can be drawn from this study. An increase in ponded ash content decreases the water demand for the mixture to meet desirable flow value. The setting time was shortened by the enhancement of cement in the production of ponded ash-backfill materials. Stiffening time was also faster with the increase in ponded ash content. At constant cement content of 90 kg/m^3 and air foam of 15%, the 28-day compressive strength of backfill material mixtures is in the range of 0.3 and 1.113 MPa. The higher ponded ash and cement content was added the higher compressive strength of the sample was achieved. This may be due to the rough surface of the ponded ash which may facilitate the formation of a strong bond with the cement. With the aim of utilizing as much as ponded ash in backfill material to facilitate the transition to sustainable construction, mixtures containing 15% air foam, 100% ponded ash, and cement content ranging from 60 to 90 kg/m3 satisfied this study target in both fresh and hardened stage.

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