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THE EFFECT OF BOTTOM ASH REPLACEMENT AS FINE AGGREGATE ON THE PROPERTY OF SHOTCRETE

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ABSTRACT: This study focused on the effect of the particle size distribution of bottom ash on the engineering properties of shotcrete. Bottom ash was used as fine aggregate replaced fine sand in the mixture of shotcrete. Particle size distribution of aggregate in this test consists of upper boundary and lower boundary of gradation No.1 in ASTM C33 and aggregates passed sieve No.4. The mixture of shotcrete was a combination of Portland cement and fine aggregate is the ratio of 1:3. Water to cement ratio is 0.6. The results demonstrated the compressive strength of shotcrete used bottom ash as an aggregate was less than normal shotcrete approximately 45%. This is due to the particle strength of bottom ash is less than sand. The compressive strength of the samples contains bottom ash passed sieve No.4 gave the highest strength. The compressive strength of the samples contains the lower boundary and upper boundary of gradation No.1 was 7.7 MPa and 10.6 MPa. However, the compressive strength of the samples contains bottom ash passed sieve No.4 was 12.6 MPa. The results of slump flow demonstrated the slump flow of shotcrete tends to increase with the reduction in the particle size of aggregate. Nevertheless, setting time tends to decrease with the reduction in the particle size of aggregate. In conclusion, bottom ash passed sieve No. 4 was the most efficient to use as fine aggregate in the mixture of shotcrete.

Keywords: Bottom ash, Shotcrete, Particle size, Lightweight

1. INTRODUCTION

Area 4.1 located at the northeast side of the pit wall in Mae Moh mine as shown in Fig. 1. According to the mine plan, K and Q seams (green layer and red layer in Fig.1) of lignite must be excavated [1]. The cut and fill method become a suitable method was used to excavate lignite in this area. The area will be mined and partially undercut. After completion of mining, backfilling will begin to support the slope face and maintaining adequate room for mining activities. The mining- backfilling cycle is iterative until all the lignite in area 4.1 is completely mined out. It is necessary to fill the current pit and cut the neighboring slope in a subsequent procedure [1, 2].

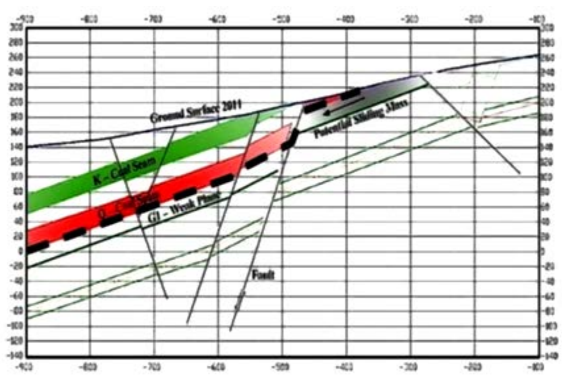

Fig. 1 Cross section plot of area 4.1 [1]

Claystone has been used as a backfill material to counterweight and supported the potential mass. However, claystone deteriorated when it has been exposed to weather change. This is a cause of the decrease in the stability of backfill [3]. The literature review demonstrated claystone protected from a weather change can maintain a physical characteristic of claystone and shear strength of backfill [3]. Thus, shotcrete becomes the suitable stabilization method to maintain the stability of backfill slopes. Shotcrete is often used for temporary protection of exposed rock surfaces that will deteriorate when exposed to air and also used to permanently cover slopes or cut that may erode in time or otherwise deteriorate [4].

Normally, the mixture of normal shotcrete consists of cement, sand, and water. The unit weight of normal shotcrete was approximately 2.2 T/m^3 [5]. In order to the reduced unit weight of shotcrete, bottom ash is a good alternative to be used as fine aggregate in the mixture.

This study focused on the lightweight shotcrete by using bottom ash replacement as fine aggregate. Bottom ash is by-product materials from Mae Moh power plant. The particle size of fine aggregate should comply with the quality requirements of ASTM C 33. Table 1 shows acceptable grading limits. Grading No. 1 was used in this test [4]. Grading No.1 shown the lower and upper limit of the aggregate. The different size distribution of aggregate influenced to fresh and hardened properties of shotcrete. Thus, the influence of particle size distribution of fine aggregate can be suggested a lower and upper limit properties of shotcrete.

Table 1 Grading Limits for Aggregate [4]

Sieve Size	Percent by Mass Passing Individual Sieves		
	Grading No.1	Grading No.2	Grading No.3
¾ inch			100
½ inch		100	80-95
3/8 inch	100	90-100	70-90
0.19inch(No.4)	95-100	70-85	50-70
0.093inch(No.8)	85-100	50-70	35-55
0.046inch(No.16)	50-85	35-55	20-40
0.024inch(No.30)	25-60	20-35	10-30
0.012inch(No.50)	10-30	8-20	5-17
0.006inch(No.100)	2-10	2-10	2-10

2. BOTTOM ASH

Bottom ash (BA) is solid waste from the combustion of coal. The annual output of lignite bottom ash in the Mae Moh power plant in the north of Thailand is around 0.8 million tons and is disposed of a landfill near the power plant. Several types of research on the utilization of coal bottom ash for use as cementitious material have been conducted.

The bottom ash has to be ground to increase the pozzolanic activity and used to partially replace Portland cement. The utilization of bottom ash as a cementitious replacement material has not yet been well received as it needs grading and only a partial replacement of cement is possible. Moreover, the bottom ash itself is porous and increase the water requirement of the mix. On the other hand, the grinding of coal bottom ash results in a prolonged setting time and causes a reduction in the workability of the paste. The as-received bottom ash particles were relatively large and very irregular, showing agglomeration of some spherical particles and other fragments with observable pores. The chemical composition of BA was 39.3 % SiO_2, 21.3% Al_2O_3, 13.5% Fe_2O_3, 2.1% K_2O, 16.5% CaO, 1.0% Na_2O and 1.4% loss of ignition [5].

Typically, the bottom ash contains assorted size closer to the sand. The gradation 50-90 percent passing sieve No.4, 10-60 percent passing sieve No. 40 and 0-10 percent passing sieve no.200. The maximum particle size is 19.0-38.1 mm. However, the particle size of bottom ash depends on the source [6]. The density of mortar which replacement of sand with bottom ash can be reduced by approximately 0.4 T/m^{3}due to a particle of bottom ash has a high porosity [7].

3. MATERIALS PREPARATION AND MIX PROPORTION OF SHOTCRETE

Wet mix shotcrete is predominantly used because of its homogeneity in quality and high work efficiency [8]. The normal mixture proportion of shotcrete consists of sand used as fine aggregate, cement, and water. However, the mixture proportion of lightweight shotcrete consists of bottom ash used as fine aggregate, cement, and water.

Ordinary Portland cement type 1 is used throughout the experiments. Sand is coming from the natural river sand. Bottom ash obtained from a Mae Moh power plant in Lampang province of Thailand. Particle size distribution of sand and bottom ash represented in Fig.2, and Fig.3 respectively. Three different size distribution of aggregate consists of lower boundary, an upper boundary**,** and middle grade was used in this test.

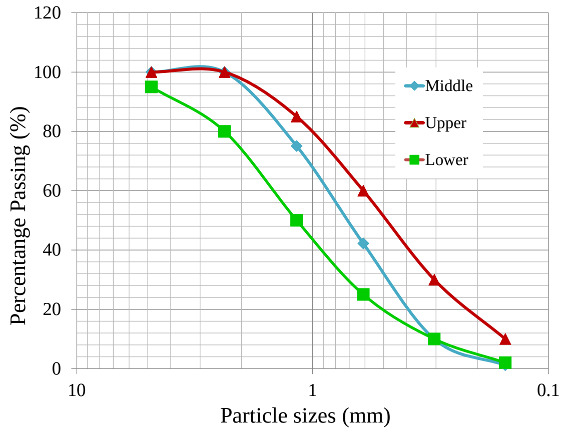

Fig. 2 Particle size distribution of sand

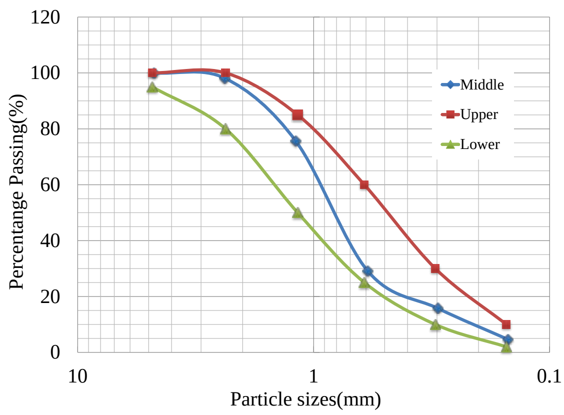

Fig. 3 Particle size distribution of bottom ash

The mixture of shotcrete in this study consist of the mixture used sand as fine aggregate and the mixture used bottom ash as fine aggregate. The three different particle size distribution of fine aggregate, according to Fig 3 and Fig 4 were used in the mixture. The mixture of shotcrete was a combination of Portland cement Type 1 and fine aggregate is in a ratio of 1:3 by weight. Water to cement ratio was 0.6.The six mixture of shotcrete shown in Table 2. The samples in the S group presented shotcrete mixed with sand and The samples in B group presented shotcrete mixed with bottom ash.

Table 2 Mix proportion of shotcrete

Mixture code	W/C	S/C,BA/C	Sand (%)	Bottom Ash(%)
SU	0.6	3:1	100	0
SM	0.6	3:1	100	0
SL	0.6	3:1	100	0
BU	0.6	3:1	0	100
BM	0.6	3:1	0	100
BL	0.6	3:1	0	100

Note: U = Upper, M = Middle, L = Lower

4. EXPERIMENTAL PROGRAM

Shotcrete mixed according to Table 1 used in the test. Fresh and hardened properties have been investigated. Fresh properties evaluation consists of the slump flow test, setting time and sagging and build-up thickness. Hardened properties evaluation consists of compressive strength.

4.1 Slump Flow

This test method is intended to be used to determine the flow of mortars, according to ASTM C 1437. Workability of mortar is its ease of use measured by the flow of the mortar. The flow table and flow mold were used to determine slump flow. The mortar sample if placed on a flow table and dropped 25 times within 15 seconds. As the mortar is dropped, it spreads out on the flow table. Measured the diameter of the mortar along the four lines. The flow is the average of the diameter of mortar on the table.

4.2 Setting Time

This test method is intended to be used to determine the initial setting time of mortar according to ASTM C191. Vicat initial time of setting is calculated as the time elapsed between the initial contact of cement and water and the time when the penetration is at 25 mm. The Vicat final time of setting is calculated as the time elapsed between initial contact of cement and water and the time when the needle does not sink visibly into a paste.

4.3 Sagging and Build Up Thickness

This test method is intended to be used to determine the thickness of shotcrete. The build-up test consists of substrates with a build thickness of framework at 300 mm. The surface of substrates was claystone backfill. The trial mixes will be plastered into an incline 300 × 300 mm by hand application to measure the build-up thickness of shotcrete as shown in Fig 4. The inclination angle used in this test was 30, 45, and 60 degrees. The thickness of the samples was 5, 8 and 10 cm. Sagging of shotcrete can be investigated by increasing the thickness of shotcrete.

Fig. 4 Sagging and Build-up thickness of shotcrete

4.4 Compressive Strength

This test method is intended to be used to determine the compressive strength of mortar according to ASTM C109. The specimen for each mixture cast in the mold of mortar at 50×50×50 mm cube specimens. Make three specimens of mortar for each period of test or test age. The specimens were cured in the water after the mortar hardened. Test the specimens immediately after their removal from storage water after 3, 7, 14, 28 and 56 days. The Universal testing machine was used to determine compressive strength

5. FRESH PROPERTIES OF SHOTCRETE

The fresh properties of shotcrete consist of slump flow, setting time and sagging and build up thickness have been investigated. The samples mixed according to Table 1 was used in the test. This section presented the workability of shotcrete. All tests are done in accordance with the American of Testing and Materials standard (ASTM).

5.1 Results of Slump Flow

The requirement for the slump flow of shotcrete should be 225±10% mm[8]. The test results of slump flow shown in Table 3 and Fig. 5.

The results demonstrated the slump flow of shotcrete used sand as a fine aggregate was between 20.0-21.0 cm. However, the slump flow of shotcrete used bottom ash as a fine aggregate was between 19.2 -20.6 cm. The results showed shotcrete mixed with aggregate at the middle size gave the highest value of slump flow. Moreover, the slump flow of BL was less than the requirement. This is due to the particle size of BL is large and bottom ash has a high porosity and high water absorption [6].

Table 3 Results of flowability

Mixture code	Slump Flow (cm)
SU	21
SM	20.5
SL	20.0
BU	20.6
BM	20.4
BL	19.2

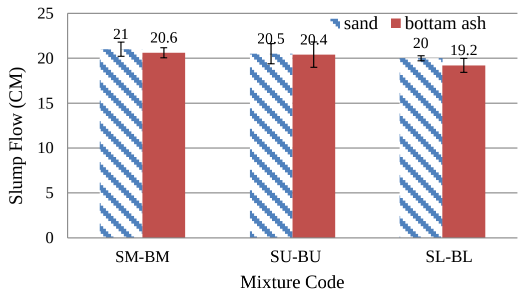

Fig. 5 Slump flow of shotcrete for each mixture**.**

5.2 Results of Setting Time

The setting time of shotcrete for each mixture presented in Table 4 and Fig. 6. The result showed the setting time of shotcrete was longer with the increased in the particle size of aggregate.

Table 4 Setting time of shotcrete for each mixture

Mixture code	Initial setting time (minute)	Final setting time (minute)
SU	142	225
SM	150	225
SL	162	270
BU	140	210
BM	151	225
BL	156	270

The initial setting time of SL was longer than SM and SU approximately 8 and 20 minutes, respectively. The final setting time of SU and SM was shorter than SL approximately 45 minute. The initial setting time of BL was longer than BM and BU approximately 5 and 16 minutes, respectively. Moreover, the final setting time of BL was longer than BU and BM approximately 60 minute and 45 minutes, respectively.

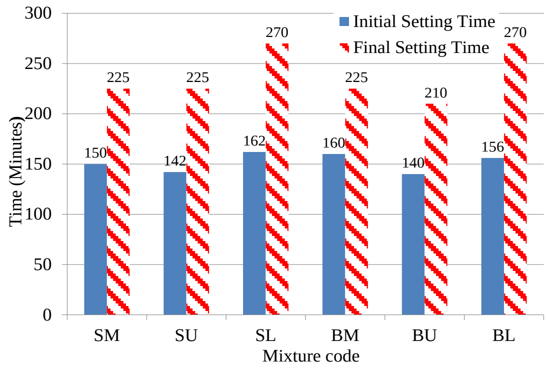

Fig. 6 Initial and final setting time of shotcrete for each mixture.

5.3 Results of Sagging and Built-Up a Thickness

Sagging and built-up thickness test was conducted on SM and BM samples. The trial mixes will be plastered on an inclined box by hand application. The inclination angle was 30, 45 and 60 degrees at the thickness 5, 8 and 10 cm. The results of sagging built-up thickness for shotcrete with different thickness and inclination angle presented in Fig 7.

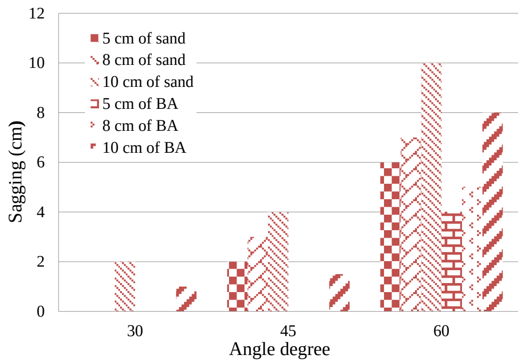

Fig. 7 Sagging and Built up the thickness of SM and BM

The results shown sagging of SM was higher than BM at the same thickness and inclination angle. This is due to the unit weight of SM was more than BM. The unit weight of SM was approximately 2.15 g/cm^3. However, the unit weight of BM was 1.70 g/cm^3. SM samples showed the highest sagging at 10 cm of thickness and the inclination angle at 60 degrees. Sagging of SM samples was approximately 10 cm. The inclination angle at 45 degrees and a thickness at 8 cm, the results showed BM samples were not sagging. However, SM samples were sagging approximately 3 cm.

6. HARDENED PROPERTIES OF SHOTCRETE

This section presented the hardened properties of shotcrete. The hardened properties investigated by compressive strength test. All tests are done in accordance with the American of Testing and Materials standard (ASTM).

6.1 Results of Unit Weight

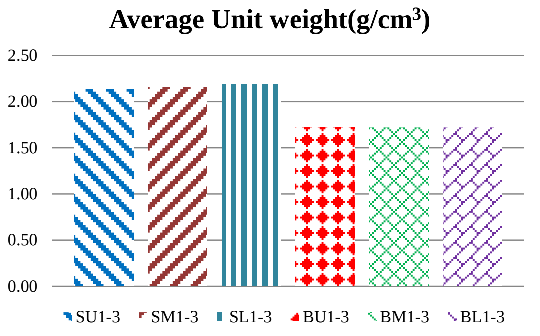

Fig. 8 Unit weight of various shotcrete mixture

The result showed the reduction in the unit weight of shotcrete used bottom ash as a fine aggregate was approximately 20% of shotcrete used sand as a fine aggregate. This is due to the unit weight of bottom ash was lower and bottom ash has high porosity. However, the different particle size distribution of aggregate slightly affects to unit weight as presented in Fig. 8.

6.2 Results of Compressive Strength

The compressive strength of shotcrete for each mixture presented in Fig.9. The results obtained from the compressive strength of shotcrete at the curing time 3, 7, 14, 28, 56 days presented in this section. Each reported value is the average of three cube specimens.

The result shown compressive strength of SU, SM and SL were slightly different in 7 days. The compressive strength of SL gave the highest at 56 days. However, the lowest compressive strength demonstrated in SU samples. At 56 days, the compressive strength of SL was higher than SU and SM approximately 12 and 21 MPa, respectively. This is due to the large particle size of sand, contain in SL samples.

The compressive strength of shotcrete mixed with bottom ash was slightly different. The results shown the compressive strength of BU, BM and BL tend to similar. The compressive strength of BU was higher than BM and BL, respectively at 56 days. This is due to BL contain a large particle size of bottom ash. The particle of them are weak and high porosity [6]. Thus, the compressive strength tends to decrease with the increase in the particle size of bottom ash. Moreover, the compressive strength of BM was less than SM approximately 25 MPa. This is due to a particle strength of bottom ash was weaker than sand.

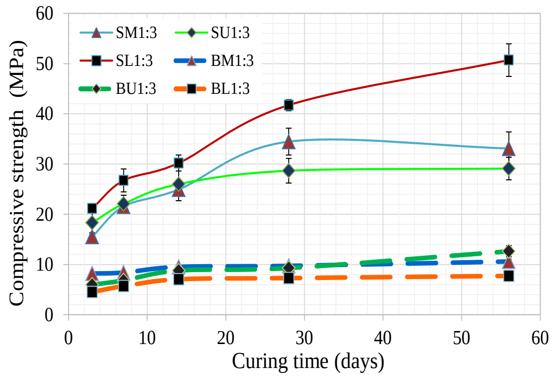

Fig. 9 Compressive strength of a various shotcrete mixture

7. CONCLUSION

Based on the results obtained from experimental in this study, it can be concluded that:

1. The mixture of shotcrete used bottom ash as a fine aggregate can be reduced the unit weight by approximately 20% of normal shotcrete.
2. The slump flow of shotcrete used bottom ash as a fine aggregate was less than shotcrete used sand as a fine aggregate. Shotcrete mixed with a middle size of aggregate gave the highest slump flow value.
3. Sagging of shotcrete used bottom ash as a fine aggregate was less than the normal shotcrete at the same thickness and inclination angle.
4. The compressive strength of shotcrete mixed with bottom aggregate was less than shotcrete mixed with sand. The middle particle size of bottom ash in the mixture gave the highest strength for shotcrete used bottom ash as fine aggregate. The compressive strength of BM was approximately 13 MPa at curing time 56 days.

8. ACKNOWLEDGMENTS

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