Recycling of waste fluidized-bed boiler ash for environment restoration of abandoned metal mine

SONG. M. S., LEE W.G., JEON S.H.
Kangwon National University, Rep. Of Korea

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1. Introduction

Fly ash is a by-product of coal combustion in a thermal power plant. Pulverized boiler fly ash is used as a cement substitute in concrete due to pozzolanic reaction. However, fluidized-bed boiler ash is inadequate to be used as a cement substitute in concrete, unlike pulverized boiler fly ash, due to a large amount of free-CaO and $CaSO_4$ generated in desulfurization process, both of which result from differences in combustion method. And so, fluidized-bed boiler ash has limited recycling and most of them are simply landfilled

On the otherhand, abandoned metal mine are the source of environmental pollution due to residue after metal mining. Leached heavy metal ions and acid mine drainage from abandoned metal mine are the most cause of environmental pollution. In this study, we used the fluidized-bed boiler ash of power plant for restore the environment of abandoned metal mines for the immobilization of heavy metal ions and neutralization of acid mine drainage. We made CLSM(Controlled Low Strength Materials, ACI 229R) by using fluidized-bed boiler ash of power plant and Blast furnace slag and others. In this study, we used abandoned zinc mine in Samcheok-city as an experimental application, and fluidized-bed boiler ash from the Korea Southern Power Co., Ltd. used for CLSM as environment restoration materials.

2. Materials

Fluidized-bed boiler ash(NFA), Pulverized boiler ash(PFA), Blast furnace slag(BFS), Desulfurized gypsum(USG)

2.1 Chemical compositions

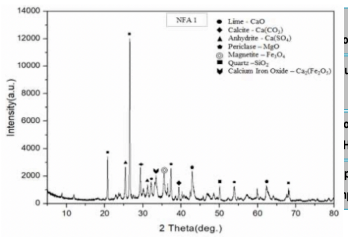
Type	Comp.(wt%)									
	SiO_2	CaO	Al_2O_3	MgO	K_2O	SO_3	Fe_2O_3	TiO_2	Ig.loss	f-CaO
PFA	51.70	16.30	19.30	2.11	1.53	0.19	6.09	1.22	1.56	0.39
NFA	27.40	22.30	12.90	8.80	0.90	0.77	25.30	0.75	0.88	5.16

Type	Comp.(wt%)								
	SiO_2	CaO	Al_2O_3	MgO	K_2O	SO_3	Fe_2O_3	TiO_2	Ig.loss
BFS	35.2	38.0	15.7	4.2	0.3	5.1	0.3	0.4	0.8
USG	2.39	90.0	0.78	2.32	0.16	2.91	0.54	0.2	0.7

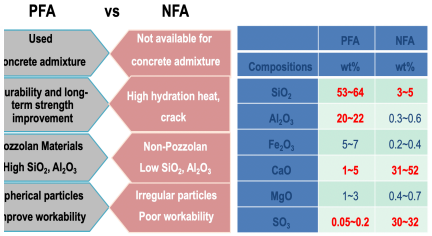
2.2 Physical properties

	Sp.gr.(g/cm³)	Blaine(cm²/g)
PFA	2.37	6,108
NFA	2.92	9,096

	Sp.gr.(g/cm³)	Blaine(cm²/g)
BFS	2.91	4,113
USG	2.69	3,569



XRD result of NFA



Compositions	PFA wt%	NFA wt%
SiO_2	53~64	3~5
Al_2O_3	20~22	0.3~0.6
Fe_2O_3	5~7	0.2~0.4
CaO	1~5	31~52
MgO	1~3	0.4~0.7
SO_3	0.05~0.2	30~32

3. Experiment

3.1 Mixing ratios for CLSM

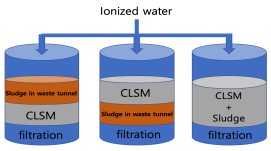
Mixing ratios

No.	W/B	NFA(wt%)	BFS(wt%)	USG(wt%)	Total
1	0.8	87.0	10.0	3.0	100.0
2		85.0	10.0	5.0	
3		77.0	20.0	3.0	
4		75.0	20.0	5.0	
5		90.0	0.0	10.0	
6		80.0	10.0	10.0	

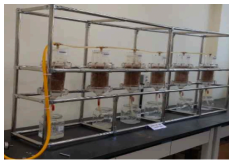
3.2 Measurement and evaluates

- Compressive strength
- Workability ; ASTM C 939, Standard test method for flow of grout for preplaced-aggregate concrete
- Column test for stablilization/solification of heavy metal ions
- Analysis of heavy metal ions ; ICP-EMS
- Abandoned metal mine tunnel filling test ; 2m*2m*40m, CLSM(NFA 90wt%) 150ton
  (2th Yuonwha mine(Samcheok-city, Rep. of Korea) is a Zn mine that was abandoned in 1997)

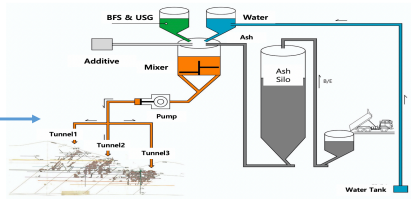
Workability test

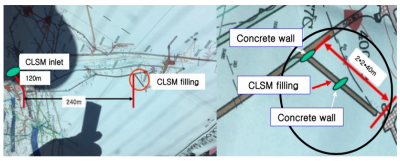


Analysis (heavy metal ions)



Column test

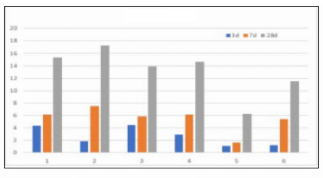




CLSM is made of waste fluidized-bed boiler ash, Controlled Low Strength Materials(ACI229R)

4. Experimental results

4.1 Compressive strength of CLSM



Compressive strength(MPa)

4.2 Workability

Workability(sec)

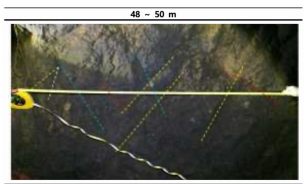
	Type	0 min	after 30 min
0	water	8.50	-
1	10-B0	35.07	Not measurable
2	10-B1	31.34	Not measurable
3	10-B2	23.63	22.45
4	10-B3	18.62	17.98

4.3 Environmental test(Column test).

Results of column test(mg/l)

Type		Heavy metal ion	Waste Sludge	After test
1	10-B2	Cu	299.7	0.015
		Pb	227.5	ND
		As	1380.49	ND
		Cd	65.01	ND
		Zn	7122.5	0.343
2	10-B3	Cu	299.7	0.041
		Pb	227.5	ND
		As	1380.49	ND
		Cd	65.01	ND
		Zn	7122.5	0.453

4.4 Stability evaluate(FLAC 2D)



Discontinuity survey of tunnel side wall

5. Conclusions

1) It was confirmed that various change of the mixing design of CLSM using fluidizes-bed boiler ash can be expressed various characteristics.

2) Compressive strength of CLSM is due to formation of carbo-ferrite hydrates, which is probably hardened by the production of Calcium Carbo-ferrite hydrate by free-CaO, sulfate and Fe compounds in fluidizes-bed boiler ash and ettringite formation by hydrate of BFS and Gypsum .

3) As a result of environmental tests of CLSM using fluidizes-bed boiler ash on the sludge and tailings of 2nd Younwha mine, the removal rate of heavy metal ions contained in the sludges and tailings was about 99% or more, and showed the excellent effect of environmental restoration with stabilization/solidification of heavy metal ions.

4) As a result of injecting the 2nd Younwha mine tunnel, CLSM using fluidizes-bed boiler ash showed excellent filling capacity and excellent filling ability in the long distance casting, and it was confirmed that it was suitable as a material for filling the abandoned mine tunnel.

5) By numerical analysis (FLAC 2D) for tunnel safety after backfill, the difference between the maximum and minimum principal stress after backfill decreases compared to before backfill, indicating that the stability is somewhat increased. In addition, since the plastic zone does not occur around the tunnel, it is determined that the tunnel stability will not be affected.

6) So, fluidizes-bed boiler ash with free-CaO, sulfate and Fe compounds can be very usefully recycled as a environmental restoration materials of abandoned metal mines

Acknowledgement

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