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Toxic Elements Leachability Tests on Autoclaved Flyash-Lime Bricks

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In this study, a series of batch leach tests was carried out to investigate the leachability of some toxic elements contained in steam autoclaved flyash-lime bricks. The prime aim of these tests was to find out whether the lime based fly ash bricks are environmentally sound. The tests simulated the natural rain water and acid rain environment to understand the behaviour of the elements during weathering. Autoclaved fly ash-lime bricks have been tested using the methods of TCLP and ASTM Method A extraction to determine their toxicity levels.

Key Words: Fly ash, Lime, Brick, Leaching test, Heavy metals.

INTRODUCTION

About 10 million tonnes of fly ash is produced yearly by the Turkish thermal power plants, most of which is sent to the ponds or landfills. The huge fly ash ponds and deponies in the vicinity of the power plants are a burden to the environment. In Turkey, fly ash has been mainly used in cement and concrete production. However, the fly ash usage is much lower than other countries due to difficulties of obtaining a fly ash product with consistent quality. Lack of research and development studies aiming at the utilization of fly ash in other industrial fields also contributes to this low usage[1].

The elements like Ti, Na, K, Mg, Hf, Th and Fe are mainly bounded in the aluminosilicate matrix of flyash whereas As, Se, Mo, Zn, Cd, W, V and U concentrate on the surface of the ash particles. Mn, Be, Cr, Cu, Co, Ga, Ba and Pb occur between the matrix and non-matrix material. In the acid soluble phases, Ca, Sc, Sr, La and rare earth elements and probably Ni are present[2–4].

The risk of the leachability of the toxic elements can be low when flyash is used as cement and concrete additive since the flyash is somewhat chemically fixed. It is often thought that high alkalinity can inhibit the mobilization of toxic elements. However, leachability tests performed with high CaO flyash suggest that the solubility of the toxic elements can be quite high[4].

In this study, batch leach tests were performed on samples of steam autoclaved flyash-lime bricks in order to investigate the leachability of soluble toxic elements.

EXPERIMENTAL

In the batch leach tests, autoclaved flyash-lime bricks produced from flyash of Seyitömer thermal power plant were used. The autoclaved bricks contain 88% flyash and 12% hydrated lime, $Ca(OH)_2$. The autoclaving pressure and time was 1.5 MPa and 6 h. The green brick forming pressure was 20 MPa. The bricks are formed in the shape of 45 mm diameter and 90 mm long cylinders.

Some physical properties of the flyash-lime bricks are given in Table-1. The chemical analysis of the bricks is given in Table-2. From chemical analysis of bricks, it can be seen that flyash bricks contain toxic elements such as Cu, Cd, Ni, Pb, Zn and Cr.

TABLE-1
PROPERTIES OF THE FLYASH BRICKS PRODUCED UNDER OPTIMUM CONDITIONS

Unit volume weight (g/cm^3)	1.08
Compression strength (MPa)	9.50
Heat conductivity (W/m K)	0.34
Water absorption (%)	46.54

TABLE-2
CHEMICAL PROPERTIES OF THE FLYASH BRICK

SiO_2 (%)	48.20	Cd (ppm)	4
Al_2O_3 (%)	14.30	Pb (ppm)	113
Fe_2O_3 (%)	7.84	Zn (ppm)	189
CaO (%)	11.50	Cu (ppm)	132
MgO (%)	4.14	Cr (ppm)	415
K_2O (%)	1.70	Ni (ppm)	867
Na_2O (%)	0.75	Mo (ppm)	0
TiO_2 (%)	0.50	Co (ppm)	57
Bao (%)	0.35	Sb (ppm)	0
SO_3 (%)	1.76	Mn (ppm)	860
Loss on ignition (%)	8.62		

The XRD pattern of the flyash-lime brick is illustrated in Fig. 1. It is found that the main phases of the flyash-lime brick are gismondine $CaAl_2Si_2O_8 \cdot 4H_2O$ (CASH) and calcium silicate $Ca_8Si_5O_{18}$ (CS).

Whole and below 100 microns ground samples of bricks were used separately for the batch leach tests. The aim of the batch leach tests was to determine the leachability of the toxic elements in neutral and acid water.

The following leach test procedures were applied on the bricks:

- TCLP (toxicity characteristic leaching procedure) [improved method 1311 (room temperature, 22 ± 3°C)].
- ASTM (American Society of Testing and Materials) Method A extraction procedure.

TCLP: This method is used to check the leaching hazards of solid wastes (it is especially suited to the acidic wastes). The method predicts the leaching behaviour of the trace elements in the disposed waste during weathering.

Leaching procedure: Weigh a piece of brick (around 40–50 g) or 10 g ground brick sample and put it into a bottle. Add distilled water for a liquid/solid ratio of L/S = 20 and glacial CH_3COOH (pH 2.88). Place the capped bottle in an agitation device for 18 ± 2 h with a shaker (at 30 ± 2 rpm) at room temperature (22 ± 3°C). Filter the eluate through 0.45 μm membrane and measure the concentrations of the

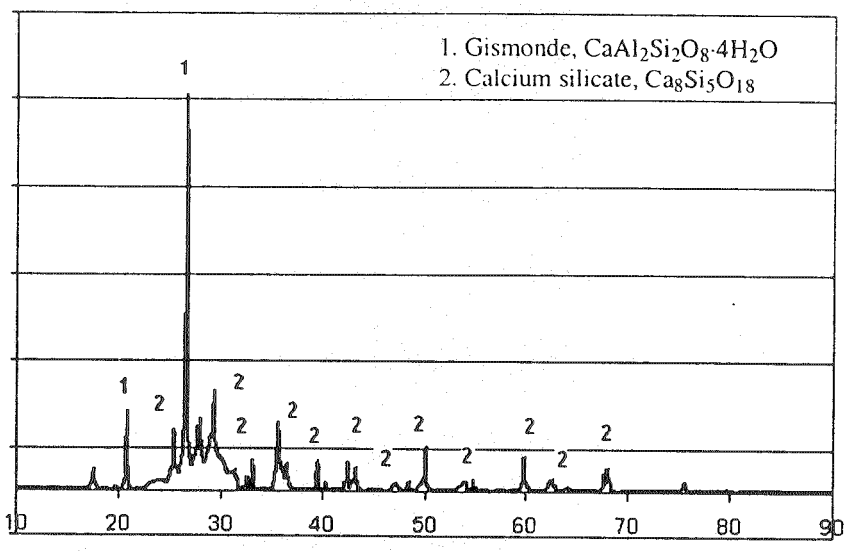

Fig. 1. XRD (X-ray diffraction) analysis of the flyash brick

leached elements. For measuring the concentration of the elements an Analytikjena AG novAA 300 flame atomic absorption spectrometer was used.

ASTM: This method is applied to predict the leaching behaviour of trace elements for long term weathering conditions. The determination of the leaching behaviour of the trace elements in long term stored wastes can be done using this method[5].

Leaching procedure: Weigh a piece of flyash-lime brick (around 40–50 g) or 10 g ground brick sample and put into a bottle. Add distilled water for a liquid/solid ratio of L/S = 20. Place the capped bottle in an agitation device for 24 ± 0.5 h with a shaker (at 30 ± 2 rpm) at room temperature (19–25°C). Filter the eluate through 0.45 μm membrane and measure the concentrations of the leached elements.

RESULTS AND DISCUSSION

Information on pH of the solutions

Two different toxicity test methods were used in this study. The first test was TCLP method which simulates the solubility of the elements contained in the flyash brick samples under a weak acid rain water environment. The other method is similar to water leaching. The pH values measured during the two different testing methods are presented in Tables 3 and 4.

TABLE-3
INFORMATION ON pH OF THE SOLUTION OF TCLP METHOD

Sample	Initial pH	Added acid (mL)	pH after adding acid	Final pH
Brick	7.8	4.94	3.20	4.75
Ground brick	10.1	1.14	5.40	7.48

In TLCP test, the ground brick sample showed a higher acid neutralization power compared to the whole brick piece which is due to higher surface area of the ground sample. In ASTM Method A extraction test, pH of the ground brick sample was 10.1 at the beginning of the test which indicates the alkaline nature of the bricks. This

property was seen to a lesser extent by the whole brick pieces. At the end of the test, however, pH value rose up to 8.6 for the whole brick, due to porous structure of the brick.

TABLE-4
INFORMATION ON pH OF THE SOLUTION OF ASTM METHOD A EXTRACTION METHOD

Sample	Initial pH	Added acid	Final pH
Brick	7.7	—	8.60
Ground brick	10.1	—	9.25

Leach results: The concentrations of the elements leached from the flyash brick samples are given in Table-5. In Table-5, the solubilities of the elements determined by two different techniques are presented to compare the methods. There were no detectable concentrations of elements in the leachates from the tests conducted with brick pieces. However, Fe, Zn, Ni and Mn could be found in the leachates from the tests run with ground brick samples. The added weak acid (acetic acid) with the TLCP method[5] changes the pH of the solution substantially, thus increasing the solubility values of the elements compared to the tests performed with distilled water. This can be seen from Ni and Mn concentrations clearly. The solubility values of these elements determined by the TCLP method are higher than the values determined by the other method of ASTM.

In the last 2 columns of Table-5 the drinking water standards according WHO[6] and TSE[7] (Turkish Standards Institute) were given. As seen from Table-5, only the dark coloured values are higher than the values in drinking water standards.

TABLE-5
CONCENTRATION OF THE ELEMENTS LEACHED FROM THE FLYASH-LIME BRICK SAMPLES

Elements	TCLP (Toxicity chacarteristic leaching procedure) improved method 1311 (mg/L)		ASTM (American Society of Testing and Materials) method A extraction procedure (mg/L)		Drinking water standards (mg/L)	
	Ground brick	Brick	Ground brick	Brick	WHO	TSE
Fe	ND	ND	42	ND	0.330	0.200
Cd	ND	ND	ND	ND	0.003	0.005
Pb	0.20	ND	ND	ND	0.010	0.050
Zn	0.70	ND	1.20	ND	3	5
Cu	0.01	ND	ND	ND	2	3
Cr	ND	ND	ND	ND	0.050	0.050
Ni	14.60	ND	2.60	ND	0.020	0.050
Co	0.12	ND	0.02	ND	0.010	**
Sb	ND	ND	ND	ND	**	0.010
Mn	18.20	ND	7.20	ND	0.4(C)	0.050

ND: Not detectable. **Not avaiable in TSE266.
C: Concentrations of the substance at or below the health based guideline value may affect the appearance, taste or odour of the water, leading to consumer complaints.

Conclusion

In this study, physical and chemical characterizations were performed on autoclaved fly ash-lime brick samples produced in the laboratory. Two toxicity tests were performed on the whole fly ash-lime brick pieces and ground brick samples to determine the solubility levels of the elements in their matrix.

The results of this study can be summarized as follows:

- The whole brick pieces are environmentally sound concerning the solubility of toxic elements. This means that the flyash-lime bricks can be used in buildings exposed to weathering.
- Fe, Pb, Zn, Cu, Ni, Co and Mn could be detected in the leachates from the tests run with ground brick samples. This indicates that the leachability of some toxic elements is promoted if the contact surface area of the bricks with water is increased by grinding of the brick samples. However, only Fe, Pb, Ni, Co and Mn concentrations in the test leachates were higher than the concentrations allowed in the drinking water standards of WHO and TSE.

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