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Toxic Elements Leachability Tests on Light Weight Fly Ash Bricks

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In present work, a series of batch leach tests were carried out to investigate the leachability of some toxic elements contained in the light weight fly ash bricks. The primary aim of these tests was to find out whether the light weight fly ash bricks were environmentally safe. The tests simulating the acid rain environment and natural rain water were conducted to gain insight regarding the behaviour of the elements during weathering. The light weight fly ash bricks were tested using the TCLP method and ASTM method A extraction to determine their toxicity levels.

Key Words: Fly ash, Fly ash bricks, Building bricks, Leaching test, Heavy metals.

INTRODUCTION

Fly ash is a by-product of coal combustion process generated by thermal power plants and about 15 million tonnes of fly ash was produced in 2000 in Turkey. This output is expected to reach 50 million tonnes by the year of 2020[1]. Most of the fly ash is sent to the ponds or landfills near power plants and the disposal is costly for electric utilities and a major concern for environment. In Turkey, only about 3 % of the total fly ash is used mainly in cement and concrete production[1]. The low amount of fly ash usage compared to those in other countries can be attributed to the inconsistent quality of the fly ash produced and lack of research and development studies aiming at the utilization of fly ash in other industrial fields[2].

Distribution of the elements within the ash structure shows differences. The elements such as Ti, Na, K, Mg, Hf, Th and Fe are mainly bounded in the alumino-silicate matrix of fly ash whereas As, Se, Mo, Zn, Cd, W, V and U concentrate on the surface of the fly ash particles. The elements such as Mn, Be, Cr, Cu, Co, Ga, Ba and Pb are intermediately distributed between the matrix and non matrix structure[3-6].

The leachability of the toxic elements can be kept at low levels[7,8] when fly ash is incorporated as an additive in cement and concrete since it is somewhat chemically fixed. On the other hand, highly alkaline fly ash is believed to materially assist to retain metals and thus inhibit the mobilization of toxic elements[9]. However, quite high concentrations of the toxic elements were also reported through the leachability tests performed with high CaO fly ash[5]. Therefore, it seems to be necessary to estimate the leaching potential of such toxic elements in assessing the possible environmental impacts associated with fly ash usage in construction industry. With this intention, batch leach tests were carried out on samples of light weight fly ash bricks to investigate the leachability of soluble toxic elements in present study.

EXPERIMENTAL

In the batch leach tests, light weight fly ash bricks produced from the mixture of the Seyitömer fly ash and the Turgutlu brick clay were used. The bricks contained 40 % fly ash and 60 % brick clay. The brick firing temperature and the dwelling time were 1050 ºC and 1 h, respectively. The bricks were formed as cylindrical logs in 45 mm diameter and 100 mm height.

Some physical properties of the light weight fly ash bricks are given in Table-1. The chemical analysis of the fly ash bricks are given in Table-2. The fly ash bricks contain toxic elements such as Ni, Cr, Zn, Pb, Cu and Cd (Table-2).

TABLE-1
PROPERTIES OF THE LIGHT WEIGHT FLY ASH BRICKS PRODUCED UNDER OPTIMUM CONDITIONS

Unit volume weight (g/cm^3)	1.20
Compression strength (MPa)	4.42
Heat conductivity (W/mK)	0.46
Water absorption (%)	25.00

TABLE-2
CHEMICAL PROPERTIES OF THE LIGHT WEIGHT FLYASH BRICK

SiO_2 (%)	63.52	Cd (ppm)	2.4
Al_2O_3 (%)	15.02	Pb (ppm)	90
Fe_2O_3 (%)	8.24	Zn (ppm)	145
CaO (%)	5.80	Cu (ppm)	72
MgO (%)	3.50	Cr (ppm)	430
Na_2O (%)	0.80	Ni (ppm)	1010
K_2O (%)	1.98	Mo (ppm)	ND
TiO_2 (%)	0.45	Co (ppm)	50
MnO (%)	0.10	Sb (ppm)	ND
SO_3 (%)	0.09	Mn (ppm)	580
Loss on ignition (%)	0.29		

ND: Not detectable.

X-Ray diffraction analyses were performed on the light weight fly ash brick containing 40 % fly ash and 60 % brick clay using a Rigaku D-max-2200/pc model powder diffractometer.The XRD pattern of the fly ash brick is illustrated in Fig. 1. It was found that the main phases of the fly ash bricks were quartz (SiO_2), albite [$Na(Si_3Al)O_8$], cristobalite (SiO_2), sodium iron silicate [$Na_5Fe(SiO_3)_4$] and sodium calcium silicate ($Na_2Ca_3Si_2O_8$).

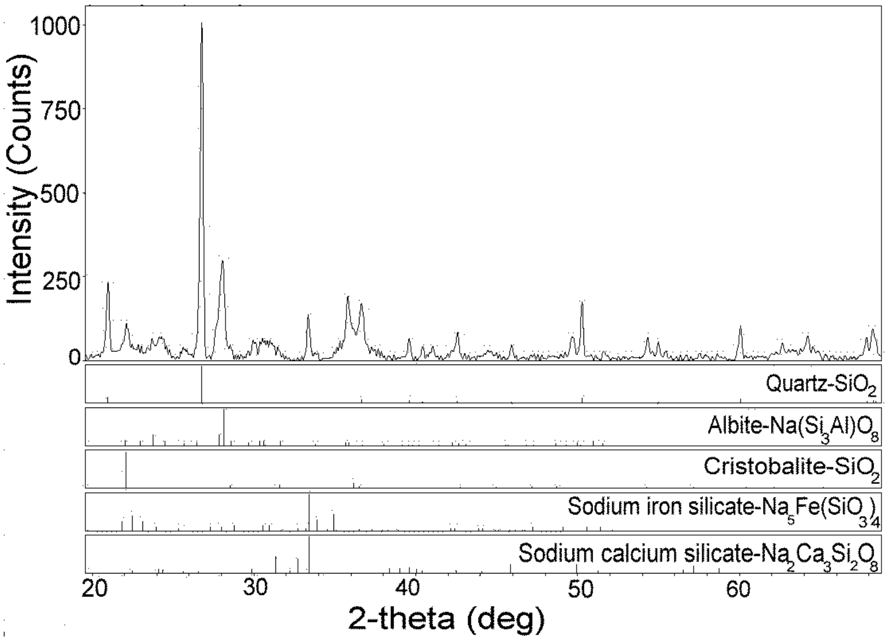

Fig. 1. XRD analysis of the light weight fly ash brick

Whole brick pieces and ground brick sample (-100 µm) were used separately for the batch leach tests. The purpose of the batch leach tests was to determine the leachability of toxic elements in neutral and acidic water. The leach test procedures applied on the bricks were as follows: (a) TCLP (toxicity characteristic leaching procedure) [Improved Method 1311], (b) ASTM (American society of testing and materials) Method A extraction procedure.

Toxicity characteristic leaching procedure (TCLP): This method is used to check the leaching hazards of the solid wastes (it is especially suitable for the acidic wastes). The method predicts the leaching behaviour of the trace elements in the disposed waste during weathering[10].

Leaching procedure: Weigh a piece of brick (100 g) or ground brick (100 g) sample and put it into a bottle. Add distilled water for a liquid/solid ratio of L/S = 20 and 11.4 mL of 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 ºC). Filter the eluate through 0.6-0.8 µm membrane and measure the concentrations of the leached elements.

American society of testing and materials (ASTM): This method is applied to predict the leaching behaviour of the 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 which is based on extended extraction with distilled water.

Leaching procedure: Weigh a piece of brick (100 g) or ground brick (100 g) sample and put it 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 ºC). Filter the eluate through 0.6-0.8 µm membrane and measure the concentrations of the leached elements.

In terms of simulating long-term leaching behaviour of the elements in natural circumstances, TCLP is considered to be too aggressive; whereas, water extraction, as in the case of the Method A extraction procedure seems to be more adequate[11].

An Analytikjena AG novaAA 300 flame atomic absorption spectrometer was used for measuring the concentrations of the leached elements.

RESULTS AND DISCUSSION

Information on pH of the solutions: The two different toxicity test methods were employed. The first one was the TCLP method simulating the solubility of the elements contained in the fly ash brick samples under a weak acid rain water environment. The second one was similar to water leaching. The pH values of the solutions measured during the two different testing methods are given in Tables 3 and 4.

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

Sample	Added acid (mL)	pH after adding acid	Final pH
Brick	11.4	2.78	3.29
Ground brick	11.4	3.79	3.82

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

Sample	Initial pH	Added acid (mL)	Final pH
Brick	5.78	-	9.15
Ground brick	9.49	-	9.85

In the TCLP test, the ground brick sample exhibited a higher acid neutralization power compared to the whole brick piece because of its higher surface area (Table-3). In ASTM method A extraction test, the pH of the ground brick sample was 9.49 at the beginning of the test indicating the alkaline nature of the bricks (Table-4). The same property was not initially observed for the whole brick pieces. However, at the end of the test, pH value rose up to 9.15 for the whole brick because of its porous structure.

Leach results: The concentration of the elements leached from the light weight fly ash brick samples are given in Table-5 in which the solubilities of the elements determined by the two different techniques are presented for the sake of comparison.

TABLE-5
CONCENTRATION OF THE ELEMENTS LEACHED FROM THE LIGHT WEIGHT FLY ASH BRICK SAMPLES

Elements	TCLP improved method 1311 (mg/L)		ASTM method A extraction procedure (mg/L)		Drinking water standards (mg/L)	
	Ground brick	Brick piece	Ground brick	Brick piece	WHO	TSE
Fe	**15.00**	0.20	ND	ND	0.330	0.200
Cd	ND	ND	ND	ND	0.003	0.005
Pb	ND	ND	ND	ND	0.010	0.050
Zn	0.75	0.05	ND	ND	3.000	5.000
Cu	0.03	ND	ND	ND	2.000	3.000
Cr	0.05	ND	ND	ND	0.050	0.050
Ni	**0.10**	ND	ND	ND	0.020	0.050
Co	ND	ND	ND	ND	0.010	**
Sb	ND	ND	ND	ND	**	0.010
Mn	**0.55**	**0.10**	ND	ND	0.4(C)	0.050

TCLP = Toxicity characteristic leaching procedure, ASTM = American society of testing and materials; ND = Not detectable. **Not available 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.

In the last 2 columns of Table-5, the drinking water standards according to WHO[12] and TSE[13] (Turkish Standards Institute) are given. As seen in Table-5, no detectable element concentrations were found in the leachates obtained from the tests carried out with brick pieces and ground brick using the ASTM method. This result strongly indicates that the leachability of the trace elements from the light weight fly ash bricks is very unlikely under the long term weathering conditions, *e.g.*, natural rain water. In a previous study[14] investigating the leachability of the soluble toxic elements contained in lime based steam autoclaved fly ash bricks containing 88 % fly ash and 12 % $Ca(OH)_2$, no detectable element concentrations were found in the leachates from the both tests conducted with brick pieces. The same results were also obtained in the present study for the whole brick sample using the ASTM method. However, in the present study, Fe, Zn and Mn were in detectable concentrations in the leach solutions obtained from the test conducted with the whole brick using TCLP method. Nevertheless, their concentrations were within the limits of WHO standards of drinking water except the Mn concentration being higher than that specified in the TSE standards of drinking water. On the other hand, Fe, Zn, Cu, Cr, Ni and Mn were found in the leach solution obtained from the test carried out with ground brick using TCLP method. Adding weak acid (acetic acid) with the TCLP method changed the pH of the solutions substantially, thus increasing the solubility values of some elements mentioned above to detectable levels in comparison to the tests performed with ASTM method using only distilled water. As seen from Table-5, only the dark coloured values are higher than those of the drinking water standards.

Conclusion

In this experimental work, physical and chemical characterizations were performed on the light weight fly ash bricks produced in laboratory scale. Two different toxicity tests were conducted on the whole fly ash brick pieces and ground brick material to determine the solubility values of the elements in their matrix. The results are as follows: (i) Although Fe, Zn and Mn were detected in the leachate obtained from the test run with the whole brick pieces using TCLP method, their solubility levels are in compliance with the drinking water standards[12,13] except the Mn concentration which is not in conformity only with TSE. Furthermore, no detectable level of any element was found in the leachates obtained from the test runs performed with the whole brick pieces and ground brick using ASTM method. Therefore, it can be concluded that the light weight fly ash bricks can be safely used in buildings exposed to weathering conditions. (ii) The solubility concentrations of the elements such as Fe, Zn, Cu, Cr, Ni and Mn from the leachate obtained from the ground brick using TCLP method were higher than those of the leachate obtained from the whole brick pieces using TCLP method. This result reflects the effect of grinding which promotes the leaching of these elements due to the increased contact surface area with the leach solution. Therefore, if the large surface areas of the bricks are somehow exposed to weathering conditions acidic in nature, the leaching of above mentioned elements might be expected. However, only Fe, Ni and Mn concentrations were determined to be higher than those allowed in the drinking water standards of WHO and TSE.

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