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Utilization of Fly Ash in Manufacturing of Building Bricks

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INTRODUCTION

Fly ash generated during the combustion of coal for energy production is one of the industrial by-products and it is recognized as an environmental pollutant. Because of environmental problem of fly ash, a good deal of work and applications on the utilization of fly ash has been undertaken worldover. Fly ash properties results primarily from the type of coal burned, the type of combustion equipment used and the fly ash collection mechanism employed.

Utilization of fly ash as a resources has been studied for decades in many areas such as in valuable element extraction, in environmental engineering, in ceramic products, in agriculture, in paint and plastic industry, in building products (brick, cement, aggregate, concentrate). Still, the utilization amount is very low. A major factor preventing utilization is the difficulty of producing quality-controlled fly ash materials that can meet market specifications.

Building bricks are usually made of a mixture of clay and sand, which are mixed and molded in various ways, after which they are dried and burned. Clay for brick making must develop proper plasticity and be capable of drying rapidly without excessive shrinkage, warping or cracking and of being burned to desired texture and strength. There are only a few detailed works on the utilization of fly ash in building bricks making. National Thermal Power Corporation Ltd., R&D Center in India has done considerable in-depth work for ash utilization such as studying the fly-ash-lime-gypsum system for brick making.[1] Although it was found that the fly ash could be used to produce bricks conforming to the standard quality by autoclaving method at the moulding pressure of 240 kg/cm^2, there were some unsolved problems with the fly ash bricks such as; higher water adsorption, low resistance to abrasion, low fire resistance and high porosity. Similar study was carried out by the same corporation above by using high pressure molding.[2] The study of brick manufacturing with fly ash from Illinios coals also showed that fly ash can be used advantageously without any significant adverse effect on quality of produced bricks.[3]

The disposal and utilization of fly ash represents a significant challenge for Turkey. In 2000, 15 million tons of ash were generated by power plants alone (not including industry and other coal utilization applications). By the year 2020, ash production is expected to reach 50 million tons per year. Presently, most of the ash is disposed of close to the power plants, except for Elbistan, which disposes part of it back into the coal mine. Only a very small percentage of ash (less than 1%) is being utilized for construction applications.

MATERIALS AND METHOD

Fly ash and brick clay were the test materials in this study. The fly ash with a density of 2.00 g/cm^3 was taken from the Çayırhan Thermal Power Plant and brick clay with a density of 2.61 g/cm^3 was taken from a brick factory located near Ankara. The brick clay was dried in an open atmosphere and crushed to –28 mesh (0.589 microns) with hammer mill. Chemical analysis and sieve analysis of fly ash and brick clay are tabulated, respectively, in Table 1 and Table 2.

Table 1. Chemical Analysis of Fly Ash and Brick Clay

Compound	Fly Ash %	Brick Clay %
P_2O_5	0.16	0.19
SiO_2	48.31	51.29
Fe_2O_3	9.27	6.18
Al_2O_3	19.25	20.92
TiO_2	1.09	1.14
MgO	4.94	2.06
CaO	10.91	8.04
SO_3	0.41	0.35
Na_2O	1.59	0.66
K_2O	1.65	0.60
Loss on Ignition	2.38	8.11

Table 1 indicated that both fly ash and brick clay have similar chemical composition. The most significant difference was observed on loss on ignition percent.

Table 2. Dry Sieve Analysis of Fly Ash and Brick Clay

Particle Size (Micron)	Fly Ash Weight %	Brick Clay Weight %
+0.589	2.63	18.63
-0.589+0.417	2.95	13.16
-0.417+0.295	5.33	13.75
-0.295+0.208	7.30	11.23
-0.208+0.147	10.08	10.30
-0.147+0.104	15.63	9.37
-0.104+0.074	16.55	7.98
-0.074+0.044	18.43	5.50
-0.044	21.10	10.08
Total	100.00	100.00

X-ray diffractometry (XRD) analysis were applied on both brick clay and fly ash samples. The XRD pattern of random specimen of the fly ash sample provides the presence of non-clay minerals; plagioclase anhydrite, hematite, amorphous silicate and zeolite in the decreasing order (Figure 1).

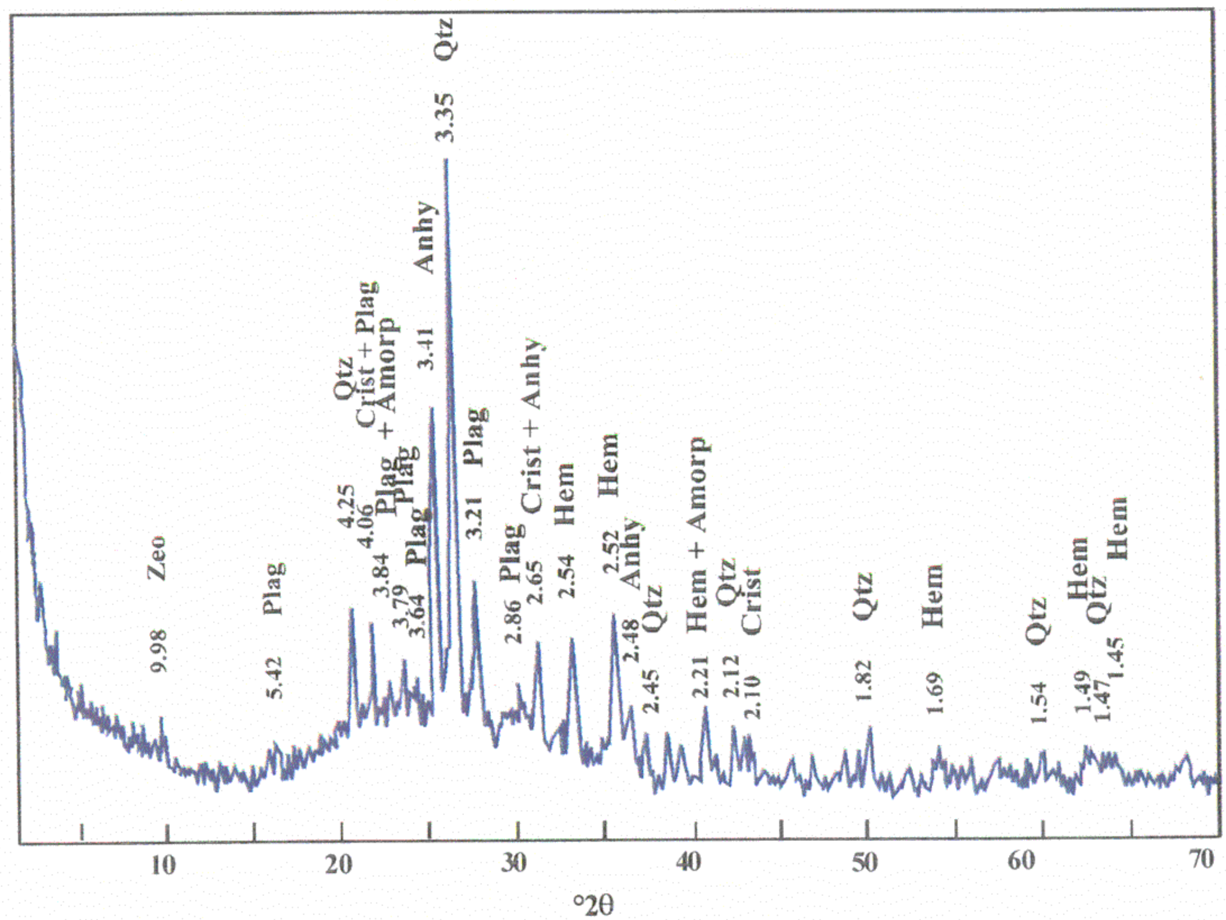

Figure 1. X-Ray Diffraction Pattern of Random Fly Ash (Crist: Cristobolite, Qtz: Quartz, Hem: Hematite, Plag: Plagioclase, Anhy: Anhydride, Zeo: Zeolite, Amorp: Amorphous)

The XRD pattern of the random brick clay specimen indicates the presence of non-clay minerals; quartz, calcite, K-feldspar and clay minerals; chlorite, smectite, mica (Figure 2).

Three kinds of brick mud containing 40.50 and 60 percent fly ash were prepared. In the light of preliminary tests optimum water amount was found as 5% for the bricks manufactured completely from the brick clay 15% for the bricks group with 40% fly ash, 20% for the 50% fly ash and 30% for the 60% fly ash. Bricks were formed under the load of 300 kg/cm^2 by using cylindrical mold having a diameter of 38.8 mm and height of 81 mm. The brick specimens were weighed for plasticity water test and measured in length for drying and shrinkage tests. These bricks were dried in an open atmosphere for three days and fired in a metallurgical furnace at selected temperatures of 750°C, 850°C and 950°C for ½ hours. After drying and firing, weighing and measuring were repeated. Finally, in order to check the conformity of fly ash addition , compressive strength tests, water adsorption tests, frost resistance tests, harmful magnesia and lime tests, shrinkage tests, plasticity water, firing loss and weight per unit volume tests were carried out at least on five bricks and the averages of the results were reported here in.

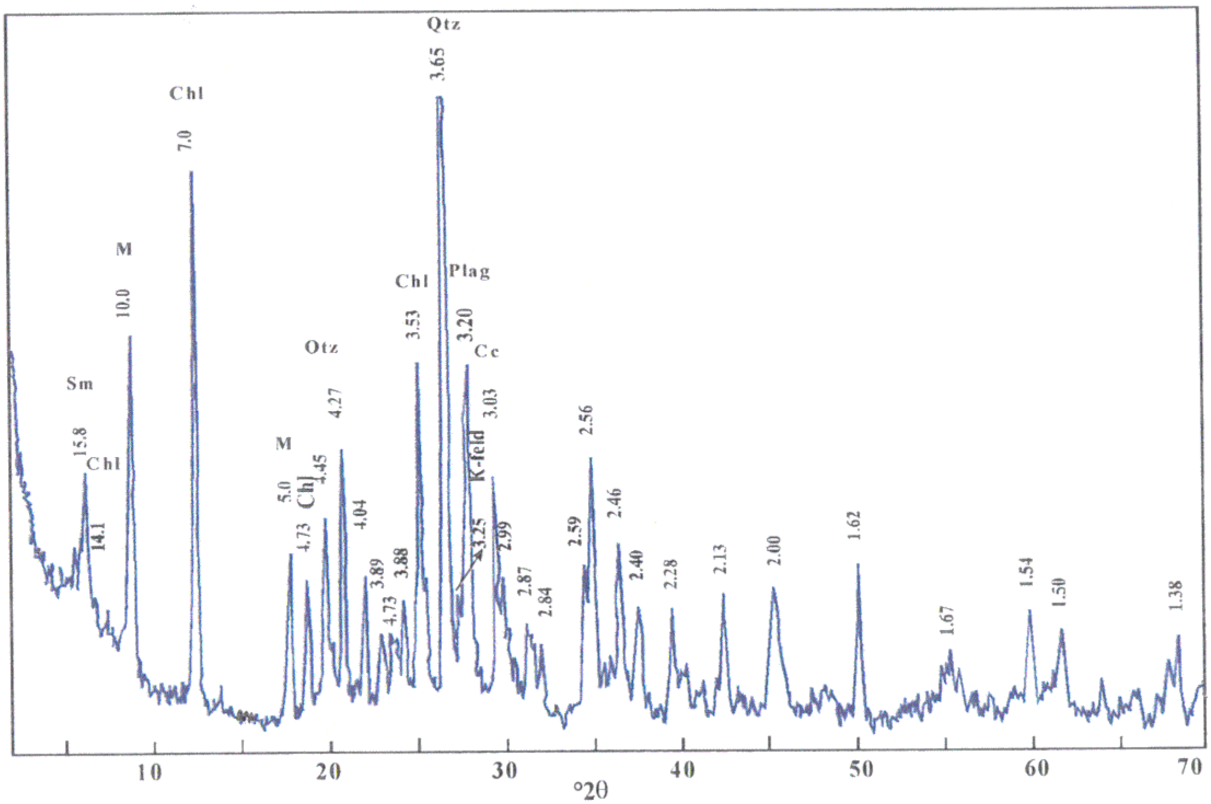

Figure 2. X-Ray Diffraction Pattern of Random Brick Clay (Chl: Chlorite, Qtz: Quartz, M: Mica, K-Feld: K-Feldspar, Plag: Plagioclase, Cc: Calcite)

RESULTS AND DISCUSSION

Several test methods were applied on bricks to check the suitability of fly ash addition to ordinary brick clay. Average values of compressive strength test results are plotted in Figure 3.

The compressive strength of fly ash bricks increased with increasing the temperature and decreasing the amount of fly ash as an additive. This may be due to insufficient plasticity of brick mud containing high amount of fly ash.

The average values of drying and firing shrinkages, water adsorption, weigth per unit volume and firing loss of bricks are tabulated in Table 3.

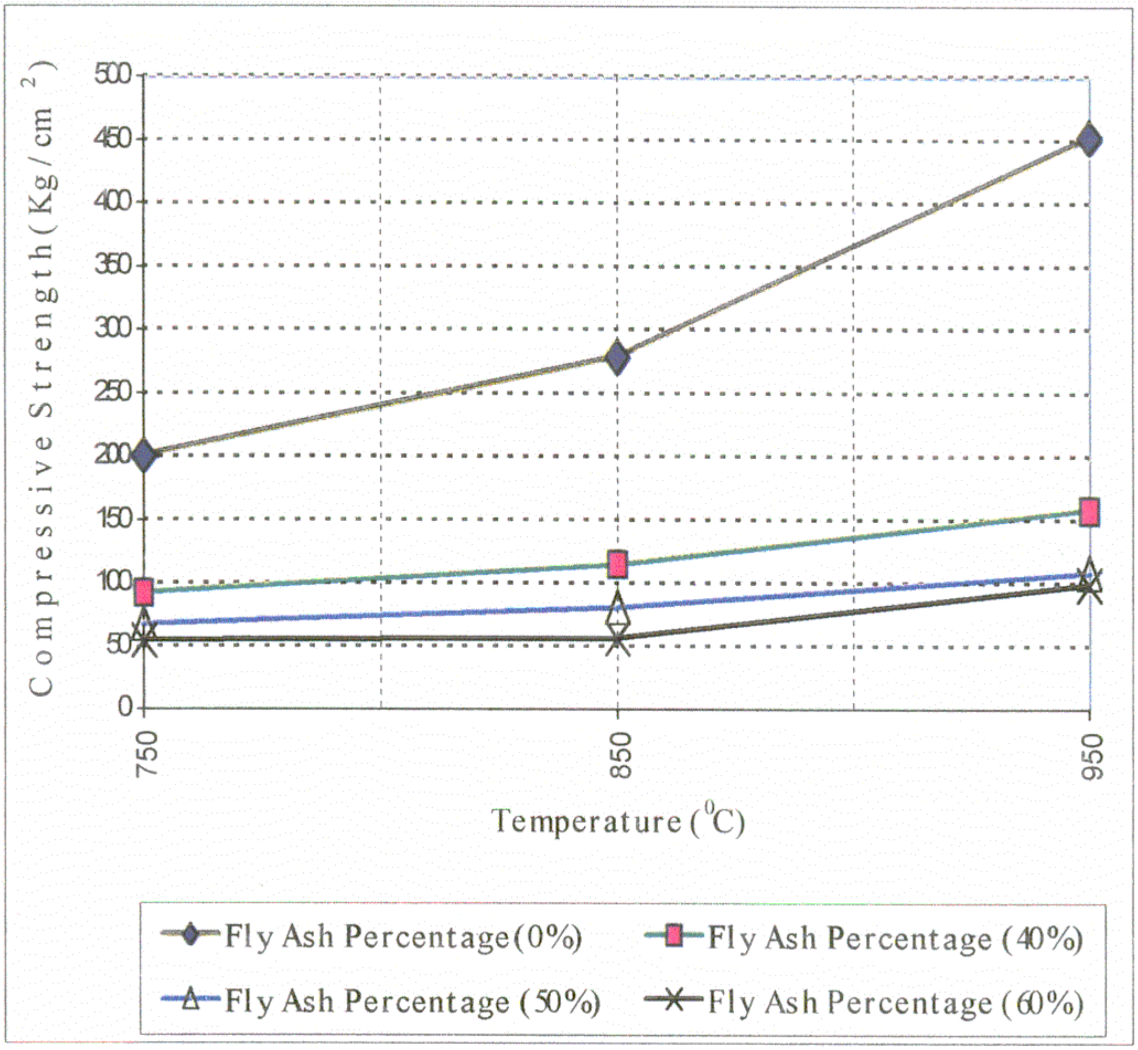

Figure 3. Compressive Strength of Bricks.

Table 3. Results of Some Standard Tests for Bricks

Fly Ash %	Dry Shrinkage %	Firing Temp. °C	Firing Shrinkage %	Water Adsorption %	Weight per unit volume kg/cm^3	Firing Loss %
0		750	0.33	15.53	1793	8.21
0	1.30	850	0.35	15.41	1827	9.90
0		950	0.40	15.33	1867	12.07
40		750	0.27	20.63	1443	5.82
40	1.32	850	0.29	19.49	1463	6.63
40		950	0.47	20.06	1491	7.77
50		750	0.28	21.49	1374	5.30
50	0.93	850	0.55	20.28	1375	5.47
50		950	0.56	20.47	1379	6.05
60		750	0.29	21.33	1312	5.20
60	1.01	850	0.66	21.63	1355	5.25
60		950	0.68	21.52	1372	5.93

The drying shrinkages of bricks group with 50% and 60% fly ash are significantly lower than the drying shrinkages of bricks group, which is completely manufactured from the brick clay. On the other hand, firing shrinkage increased with increasing the firing temperature and the amount of fly ash as an additive. The water absorbtions of bricks containing fly ash are higher than that of brick manufactured completely from brick clay. Weight per unit volume of bricks decreased with increasing the amount of fly ash as an additive and increased with increasing the firing temperature.

The compressive strength value of bricks in Table 4 indicated that there was a little decrease in the compressive strength values after the frost resistance test and harmful lime-magnesia tests but no cracking and deformation were observed on the bricks.

Table 4. Compressive Strength of Bricks After Frost Resistance and Harmful Lime-Magnesia Test

Firing Temp. (°C)	Ash %	Compressive Strength (kg/cm^2)		
		Original Bricks	After Frost Resistance Test	After Harmful Lime-Magnesia Test
750	0	205.52	191.23	189.73
	40	94.57	86.31	83.07
	50	69.40	62.38	60.03
	60	60.43	-	-
850	0	264.12	263.12	252.62
	40	117.83	110.20	107.31
	50	84.93	75.61	70.70
	60	61.58	-	-
950	0	452.47	334.36	364.56
	40	163.68	154.42	148.56
	50	109.13	108.1	100.6
	60	102.35	82.48	70.70

CONCLUSIONS

The addition of fly ash up to 60% at a firing temperature as 950°C has no significant harmful effects on the brick quality. It seems that the fly ash added building bricks show reasonably good properties and may become competitive with the conventional building bricks. Use of fly ash as a raw material for the production of building bricks is not only a viable alternative to clay but also a solution to a difficult and expensive waste disposal problem.

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