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Use of fly ash in production of light-weight building bricks

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HIGHLIGHTS

- Real-size fly ash/lime bricks were produced in a steam autoclave.
- Tobermorite and katoite were formed as binding phases in bricks.
- Single axis compressive strength of the bricks was 76.5 kg f/cm^2.
- The thermal conductivity of the bricks were measured as 0.225 W m^{-1} K^{-1}.

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ABSTRACT

Fly ash is one of the coal combustion products (CCPs) of coal burning power plants and it contains substantial amounts of potentially harmful constituents to the environment. It is known that nearly 600 million tons of fly ash is produced in the world per-annum. In Turkey, the annual production of fly ash is, on average, 13 million tons and only a small amount of this is utilized. This study examines the production of light-weight, high thermal insulating bricks made out of the fly ash and lime. Cylindrical brick samples were produced through steam curing of Seyitömer thermal power plant fly ash and lime mixtures in an autoclave in order to determine the optimum conditions for mechanically sound bricks. Subsequently, at the optimum conditions determined, real-size bricks were produced and subjected to standard tests. The findings of this paper suggest that fly ash/lime bricks can be an alternative product to aerated cellular concrete.

1. Introduction

The fly ash generated during coal combustion process in thermal power plants represents a major environmental problem. According to 2013 data, in Turkey, 25.7% of total energy production is supplied from coal burning power plants [1]. Worldwide production of fly ash is 600 million tons per-annum whereas Turkey's annual production is, on average, 13 million tons [2].

The number of the studies concerning with the characterization and industrial utilization of fly ash have increased substantially over the years. These studies focus primarily on properties, classification and determining possible areas of usage of fly ash. Depending on the properties of fly ash, many areas of application mainly in sectors of cement, ceramic, paint, plastic, agriculture, environment and construction were suggested in relevant literature [3–8]. Fly ash is widely used in production of cement, concrete, cellular concrete, bricks, lightweight construction aggregate and soil stabilization [9]. In some countries, by the raising environmental concerns, the use of fly ash in different industries has been promoted and even regulated by the governments through legislations. For example, the clay brick industry has to incorporate at least 25% fly ash in the brick making mixture if the clay brick facility is within 100 km from a coal power generation plant in India [10].

Fly ash is of synthetic pozzolanic character that is thought to be provided by the aluminates and amorphous silicate minerals that fly ash contains [11]. Pozzolanic ash has the ability to react with slaked lime and water [12]. The reaction occurring between lime and silica occurs based upon $CaO–SiO_2–H_2O$ (C–S–H) formulation [13–16]. Hydration reactions can also take place to form $CaO–Al_2O_3–SiO_2–H_2O$ (C–A–S–H) phases contributing to the strength of the final product [17]. In order to achieve that and to accelerate the reaction kinetics, curing process should be conducted under pressurized steam at 125–200 °C in an autoclave. This property of fly ash provides an important advantage for the utilization of fly ash in production of construction materials.

The use of fly ash in construction materials and concrete production is relatively low in Turkey when compared to that of Germany, the Netherlands, United Kingdom, United States and

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China [8,10,18]. Some studies were focused on production opportunities of building bricks using fly ash [19–21]. Demir used the method of firing Seyitömer power plant fly ash/clay bricks and obtained successful results [22]. Another study that employed the method of curing under high pressure steam using the Seyitömer fly ash, slaked lime and sand at pre-determined ratios, also obtained encouraging results [17]. Recently, studies were conducted towards the leaching behavior of heavy metals from fired [23] and autoclaved [24] fly ash–lime bricks. The former was composed of 40% Seyitömer fly ash and 60% brick clay while the latter was containing 88% Seyitömer fly ash and 12% hydrated lime. In both studies, TCLP [25] (toxicity characteristic leaching procedure) [Improved Method 1311] and ASTM [26] Method A extraction procedure were conducted on the whole fly ash brick pieces to determine the solubility values of the elements in their matrix. TCLP method, simulating the solubility of the elements contained in the fly ash brick samples under a weak acid rain water environment, is used to check the leaching hazards of the solid wastes (it is especially suitable for the acidic wastes). The results for autoclaved fly ash lime bricks showed that the bricks produced with Seyitömer fly ash were environmentally sound in terms of the solubility of toxic elements.

This study dealt with fly ash/lime bricks cured under high pressure steam. The main contribution of this study is the production of real size fly ash/lime bricks using a pilot scale autoclave.

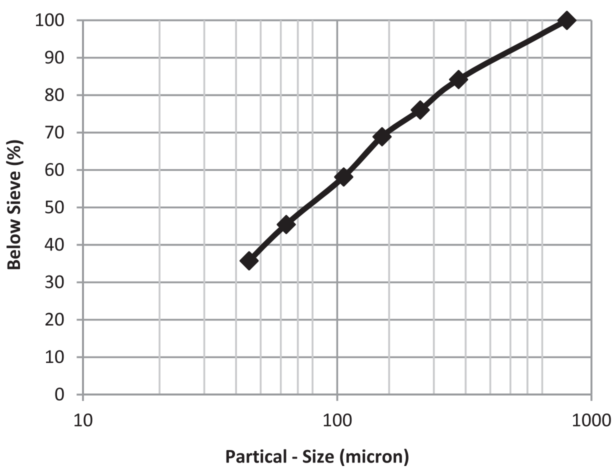

Fig. 1. The particle-size distribution of fly ash sample from Seyitömer power plant.

2. The material and the method

The fly ash from Seyitömer power plant and slaked lime are used in this study. The particle-size distribution of the fly ash sample is given in Fig. 1. The graph shows that particle size of the sample is below 800 μm and 0/212 μm fraction makes up 76.06% of the ash. The material was also subjected to chemical analysis for determining its composition and the results are tabulated in Table 1.

As can be seen in Table 1, the amount of unburnt carbon is higher in the coarse fraction (212/800 μm: 8.41%) compared to 0/212 μm sieve fraction which contains 1.75% unburnt coal. It is found that the free lime content of this fraction is only 0.32%. No abnormalities were observed in the individual sieve fractions of fly ash concerning chemical composition.

Based on the data presented in Table 1, $SiO_2 + Al_2O_3 + Fe_2O_3$ (S + A + F) ratio of 0/212 μm sieve fraction was calculated as 83.99% and CaO ratio was determined as 5.34%. Based on this values, Seyitömer fly ash can be classified as F type of low-lime fly ash according to ASTM C 618 standard [27].

Table 1
The chemical analyses of fly ash sample from Seyitömer power plant.

Particle size (μm)	Weight (%)	Ignition loss (%)	SiO_2 (%)	Al_2O_3 (%)	CaO (%)	MgO (%)	Na_2O (%)	K_2O (%)	MnO (%)	Fe_2O_3 (%)	TiO_2 (%)	SO_3 (%)	Free CaO (%)
800/300	15.8	10.08	–	–	–	–	–	–	–	–	–	–	
300/212	8.14	5.17	–	–	–	–	–	–	–	–	–	–	
800/212	23.94	8.41	–	–	–	–	–	–	–	–	–	–	
212/150	7.15	3.5	58.94	17.27	3.97	4.01	0.62	2.03	0.07	8.96	0.16	0.43	
150/106	10.75	2.19	57.63	17.56	5.16	4.04	0.79	2.21	0.09	9.55	0.15	0.59	
106/63	12.7	1.5	57.53	17.42	5.32	4.13	08	2.53	0.09	9.7	0.13	0.8	
63/45	9.7	1.25	57	17.7	5.55	4.14	0.84	2.59	0.1	9.59	0.14	1.05	
45/0	35.76	1.5	55.54	17.13	5.62	4.12	0.84	2.81	0.12	10.53	0.13	1.62	
212/0	76.06	1.75	56.67	17.33	5.34	4.1	0.81	2.58	0.1	9.99	0.14	1.15	0.32

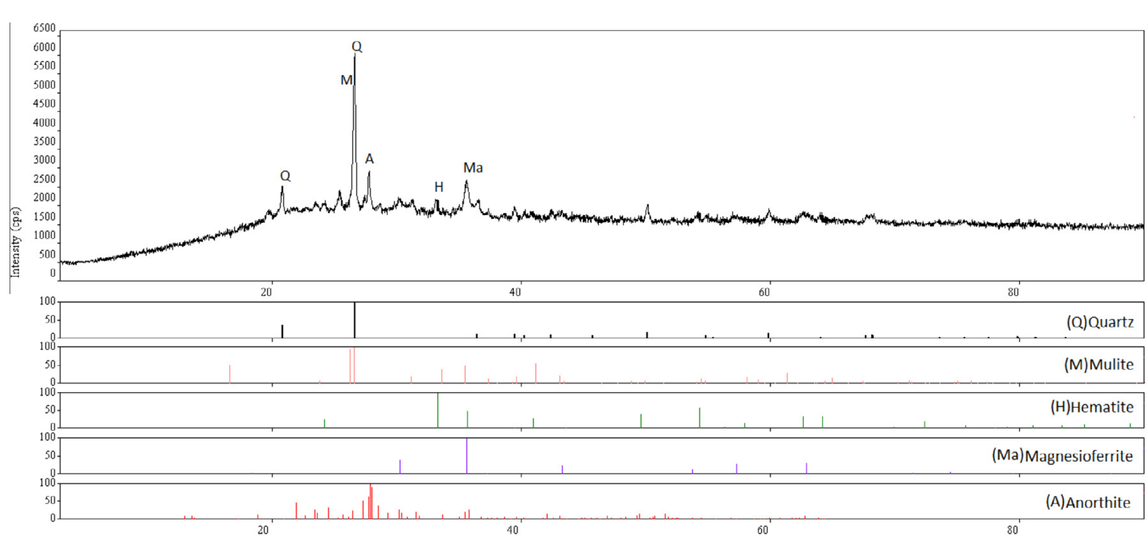

Fig. 2. The X-ray diffractogram of Seyitömer fly ash sample.