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Recycling of Coal Ash in Production of Low Density Masonry Unit

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Coal ash is a residue that is created when coal is burned by power plants to produce electricity. Coal ash is one of the largest types of industrial waste and causes environmental pollution. On the other hand, coal ash is potentially a valuable source of minerals, including SiO_2, Al_2O_3, CaO, MgO, Fe_2O_3, Na_2O and K_2O. This study aims to recycle the coal ash in production of low density masonry unit. Coal ash was characterized by chemical and X-ray diffraction analyses. The batches containing different ratios of coal ash and a brick making clay were prepared and shaped by cold pressing. The pressed samples were fired at 1050 and 1100 °C. The physical properties such as water absorption, apparent porosity, linear shrinkage, and bulk density were determined. Microstructural observations were performed by using scanning electron microscopy. Based on the technological characteristics; it was observed that low density masonry units can be produced by using coal ash. This study supports the responsible recycling of coal ash by distinguishing beneficial use from disposal.

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PACS/topics: coal ash, recycling, low density, masonry unit

1. Introduction

Nowadays usage and recycling of industrial wastes have become an important research area. Manufacturers and customers require high quality products with low cost. Therefore, in addition to finding alternative raw materials, recycling wastes as a possible replacement has gained considerable interest. Waste management is a very important matter both for environmental perspective and the industrial point of view, because increasing amount of residual materials need to be consumed in a safe and economical way. Recycling of industrial wastes, as alternative raw materials is not a new thing and has been studied since few years in a lot of countries. The problems related to waste production are becoming more and more important in relation to the improvement of economical conditions, the progress of industrial development and the population and urban increase. For that reason, there is an effort in extending the application of waste mainly by innovative technologies for the manufacture of new products [1–12].

When coal is burned, 4–25 wt% of the coal is converted to ash. Coal ash is a waste product that contains valuable source of minerals such as SiO_2, $A1_2O_3$, CaO, MgO, Fe_2O_3, K_2O and TiO_2, which are found in common glass and ceramic materials [13]. Coal ashes are generally classified by international normative (e.g. European 75/442/EEC) as ordinary industrial wastes, although they may be geochemically unstable and environmentally unsafe. Nevertheless, when properly managed it can be possible to use coal ash in environmental and economical ways and this can improve the competitiveness of the coal based energy power-plants [14].

The aim of this study is to determine the characteristics of the coal ash sample and investigate its usage in the production of clay to be used for low density masonry unit. It is thought that coal ash can be used to produce at proper additions.

2. Materials and method

The coal ash investigated in this work was obtained from a power plant that produces electricity and the clay was obtained from a brick factory. The coal ash was characterized by chemical and X-ray diffraction (XRD) analyses. The chemical composition of clay samples was determined by atomic absorption spectroscopy analysis (GBC). The phases present in the samples were identified by XRD using a Rigaku Model diffractometer with monochromatic Cu K_α radiation.

Preparation and testing of the samples were done at a laboratory scale. Compositions were formulated using coal ash at varying proportions. In order to enlighten the physical properties, pellet samples were used. To produce pellet samples, samples with different compositions was dried and ground. The ground agglomerates were then humidified up to 6 wt% water. The humid powders were pressed under 150 kg/cm^2 pressure to obtain $100 \times 50 \times 6$ mm^3 prismatic samples. The shaped samples were dried at 120 °C for 24 h and fired at 1050 and 1100 °C using a laboratory kiln (Nabertherm LH 15/14). Fired samples were used to characterize the physical properties of the materials according to TS EN ISO 10545-3 and TS EN ISO 10545-4 norms. The microstructures of

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the fired samples were analyzed by a scanning electron microscope, SEM (JEOL-JSM 6060).

3. Results and discussion

Table I lists the chemical compositions of coal ash. The main characteristic of the coal ash is its high SiO_2, Al_2O_3 content. The sample contains also considerable amounts of Fe_2O_3, CaO, K_2O and loss on ignition (LOI). XRD analysis showed that coal ash sample contains quartz, muscovite, illite, orthoclase, cristobalite, and mullite phases (Fig. 1).

TABLE I

Chemical analysis results of the coal ash sample.

SiO_2	Al_2O_3	Fe_2O_3	MgO	CaO	Na_2O	K_2O	TiO_2	LOI
44.21	23.64	3.71	1.19	2.61	0.81	2.21	0.55	20.60

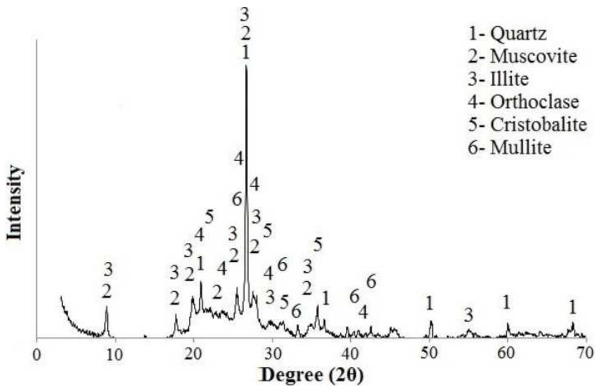

Fig. 1. XRD analysis of coal ash.

The variations in physical properties of the samples fired at different temperatures are listed in Tables II and III. R0 was selected as control specimen and the physical results were compared to that of the control specimens results. The results shows that bulk density values decrease while water absorption, apparent porosity, and linear shrinkage values increase with increasing

TABLE II

Physical properties of the samples fired at 1050 °C. A — coal ash contents [%], B — water absorption [%], C — apparent porosity [%], D — bulk density [g/cm^3], E — linear shrinkage [%].

Code	A	B	C	D	E
R1	70	38.15	47.68	1.25	5.04
R2	60	34.79	46.36	1.33	3.18
R3	50	31.99	44.71	1.40	3.03
R4	40	28.79	42.27	1.47	2.34
R5	30	25.36	39.91	1.55	1.85
R6	20	21.49	35.87	1.67	1.65
R7	10	18.42	32.90	1.79	1.29
R0	0	14.45	27.96	1.93	1.70

TABLE III

Physical properties of the samples fired at 1100 °C. A — coal ash contents [%], B — water absorption [%], C — apparent porosity [%], D — bulk density [g/cm^3], E — linear shrinkage [%].

Code	A	B	C	D	E
R1	70	32.05	43.27	1.35	5.73
R2	60	29.67	41.35	1.39	5.36
R3	50	27.08	39.62	1.46	4.58
R4	40	24.18	37.28	1.54	4.16
R5	30	24.04	38.02	1.58	2.33
R6	20	19.20	32.80	1.71	2.02
R7	10	13.50	25.93	1.92	1.51
R0	0	10.97	22.43	2.04	3.39

content of coal ash at the same firing temperature. As expected, increase in firing temperature causes enhanced densification and reduced porosity.

Shrinkage is an important property for ceramics because even a small alteration in this property can lead to related changes in the mechanical and the physical properties such as effect on cracking as well as dimension quality when firing [15]. With ash content above 40% the shrinkage values had higher values. It raises risks to use coal ash above this content.

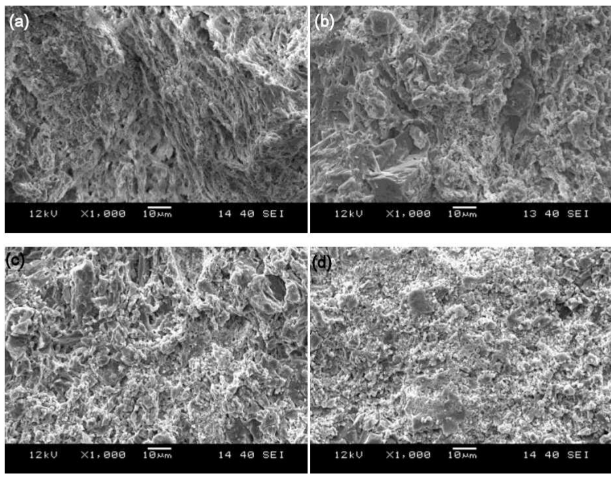

Fig. 2. SEM images of (a) R1, (b) R4, (c) R7 and (d) R0 samples fired at 1050 °C.

The microstructures of the fractured surface of samples fired at 1050 °C and 1100 °C are shown in Figs. 2 and 3. Increase in the firing temperature had an influence on the microstructure of the bodies due to the reduction of pores. Also increase in the amount of coal ash caused more porous samples. It was observed that R0 sample had denser structure. Compared to control sample, the structure of the samples became more porous with increasing coal ash content. It is reasonable to think that coal ash acted as filler and the presence of coal ash caused porosities and voids within the structure.

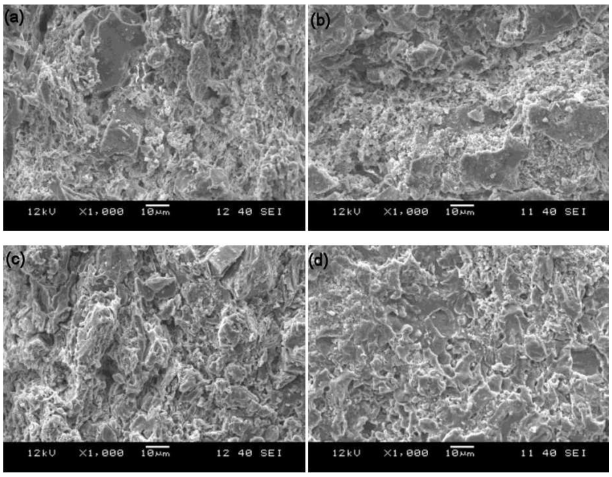

Fig. 3. SEM images of (a) R1, (b) R4, (c) R7 and (d) R0 samples fired at 1100 °C.

4. Conclusion

In this study, the characteristics of coal ash and its usage in production of low density masonry unit were investigated. From the results obtained, the following conclusions can be done.

The predominant oxides in coal ash are SiO_2, Al_2O_3, Fe_2O_3 and CaO. Quartz, muscovite, illite, orthoclase, cristobalite, and mullite are found as the main phases. The results revealed that the ash content above 40% caused higher increase in linear shrinkage values. Density of the fired samples also decreased with increasing coal ash content. Increase of the firing temperature leads to denser samples due to the improved sintering. Also porosity of the fired samples tends to increase with increasing coal ash content. Although the results of physical properties were largely positive, the ash content above 40% had an important effect on linear shrinkage, which usually influences the dimensions and the quality of the finished product. The results showed that low density masonry units can be produced by using coal ash.

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