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Characteristics of fired clay bricks with waste marble powder addition as building materials

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HIGHLIGHTS

- Fired clay bricks with marble waste were studied.
- Addition of waste marble powder increases thermal performance of brick.
- Bricks have enough strength required by standard.
- Increasing of firing temperature affects mechanical and physical properties of bricks.

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ABSTRACT

Fired clay bricks lightened by adding up to 35 wt.% waste marble powder have been produced by semi-dry pressing process. Chemical composition, phase identification, thermal behavior and microstructure of the raw materials were analyzed by XRF, XRD, TGA and SEM, respectively. The brick mixtures containing waste marble powder at different proportions were formed, dried and then fired at 950 and 1050 °C for 2 h. Properties such as drying and firing shrinkages, loss on ignition, bulk density, porosity, water absorption, compressive strength, thermal conductivity, microstructure and phase content of the fired brick samples were determined. It was found that the use of waste marble powder addition reduced the bulk density of the samples. It was observed that their porosity ratios up to about 40% improved with increasing of waste marble powder addition up to 30 wt.% for all samples, whereas their compressive strengths decreased until 8.2 MPa. However, their strengths were enough according to the values required by the standards. Thermal conductivity of the samples decreased from 0.97 to 0.40 W/mK. Increasing of the firing temperature also affected their mechanical and physical properties. This study showed that the waste marble powders could be used as a pore maker and contributing to the formation of crystalline phases in brick production at certain ratios.

1. Introduction

Bricks have been widely used as construction and building material all around the world for a long time. Conventional clay based brick production generally uses the mixtures of clays and shale as raw materials, and requires the processes of shaping, drying and firing at a high temperature. Fired clay bricks are mainly construction elements used to make walls of buildings. The worldwide annual production of bricks is currently about 1391 billion units and the demand for bricks is predicted to be continuously increasing [1,2]. In this respect, for the development of bricks with waste materials, further research and development is necessary. Besides, not only on the technical, economic and environmental features but also on standardization, government policy and public education related to waste reusing and sustainable development is required for wide production and application of these bricks. For environmental protection and sustainable development, many researchers have studied the utilization of waste materials to produce bricks. A wide variety of waste materials have been studied, including fly ash, mine tailings, slags, construction and demolition waste, wood sawdust, cotton waste, pulp and paper production residues, boron waste, cigarette butts, waste tea, rice husk ash and crumb rubber [1–10]. But, very limited information about the usage of waste marble powder to produce brick has been reported [11–14].

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Table 1
The brick mixtures prepared from the raw materials used.

Temperature (°C)	Mix code	Clay (wt.%)	Waste (wt.%)
950	A1	100	0
	A2	95	5
	A3	90	10
	A4	85	15
	A5	80	20
	A6	75	25
	A7	70	30
	A8	65	35
1050	B1	100	0
	B2	95	5
	B3	90	10
	B4	85	15
	B5	80	20
	B6	75	25
	B7	70	30
	B8	65	35

Table 2
Chemical composition of the raw materials used.

Oxides (wt.%)	Brick clay	Waste marble powder
Al_2O_3	14.9	0.87
SiO_2	59.2	3.72
Fe_2O_3	8.54	–
TiO_2	0.95	–
MgO	1.64	0.76
CaO	2.36	52.9
K_2O	2.86	0.27
Na_2O	0.96	–
Loss on ignition	8.6	41.3

Countries such as USA, Belgium, France, Spain, Sweden, Italy, Egypt, Portugal, Brazil, Greece and Turkey have considerable marble reserves. Turkey has even more, 40% of total marble reserves in the World. Seven million tons of marble are produced in Turkey annually [15,16]. In processing marble such as cutting to size and polishing etc. for decorative purposes, marble dust and aggregate are created as byproducts. Thus, waste materials from marble processing plants represent considerable tonnages. During the cutting process 20–30% of the marble block turns into dust. Such waste is often disposed near residential areas. Stocking of these wastes is difficult, hence marble wastes constitute an environmental pollutant, recently utilizing as an additive in concrete [12,15–18]. Construction industry generally uses large amounts of clay brick in most of buildings [19]. The earth cannot sustain the today's growth rate without serious impact in the future since no natural resources constitute limitless reserves [20]. Thus, some countries such as China have been brought into practice restricted laws in the form of prohibitions or special taxes for creating waste areas. For protecting clay resources and environment, some countries have started to limit the use of bricks made from clay due to a shortage of clay in many parts of the world [21]. It seems that stricter future waste disposal regulations and attempting to protect natural reserves may be applied because the disposal of the waste has become a severe social and environmental problem. In this way, it is necessary a conscious energy and ecological design which fulfill all the strength and serviceability requirements [15,22,23]. Waste marble powder can be composed of inorganic compounds such as calcium and magnesium carbonates, and also silicates; it can cause to form of new crystalline phases such as wollastonite, gehlenite and anorthite after firing in the ceramic structures, and also micro-porosities due to the decomposition of carbonates [24,25].

The aim of this work is to investigate the use of waste marble powder as additive in clay brick and its effect on the physical, mechanical and thermal properties of the clay based bricks, seeking an optimum content of waste marble and minimizing its negative impact on the environment.

2. Materials and methods

In this study, the production of fired bricks from mixtures of brick clay and waste marble powder additive was accomplished. The waste marble powder was obtained from a local marble processing factory in Bartin, Turkey. Marble is a crystalline metamorphic limestone, basically containing calcite ($CaCO_3$) and maybe, dolomite ($MgCO_3 \cdot CaCO_3$). The clay raw material was obtained from a brick manufacturer in Bartin, Turkey. The raw materials were initially subjected to pretreatments such as drying, milling and sieving; prepared by powdering in a laboratory mill to particle size smaller than 100 μm for brick production. The chemical composition of the raw materials was determined by the X-ray fluorescence (XRF) elemental analysis spectrometer. The crystalline phase or mineral content of the raw materials was analyzed by the X-ray powder diffraction (XRD). Their thermal behaviors were performed by thermo-gravimetric analysis (TGA). Also, the microstructural morphology and elemental maps of the raw materials were investigated by scanning electron microscopy (SEM) analysis with energy dispersive spectrometer (EDS).

The brick clay mixtures-without and -with waste marble addition was prepared in a mechanical mixer. Mixture proportions were presented in Table 1. The raw materials were mechanically mixed for 30 min to get a uniform consistency. After dry mixing, water about 15 wt.% of total weight was sprayed to the powder mixtures for the production of semi-dry molded brick samples. A hydraulic press was used to make bricks pellets with 20 mm in diameter and 10 mm length. Semi-dry mixtures were compressed with a pressure of 40 MPa. After shaping of bricks, they were left to dry in ambient conditions for 24 h. Samples were dried in an oven maintained at 40 °C for 12 h and then at 110 °C for 24 h. Two firing temperatures

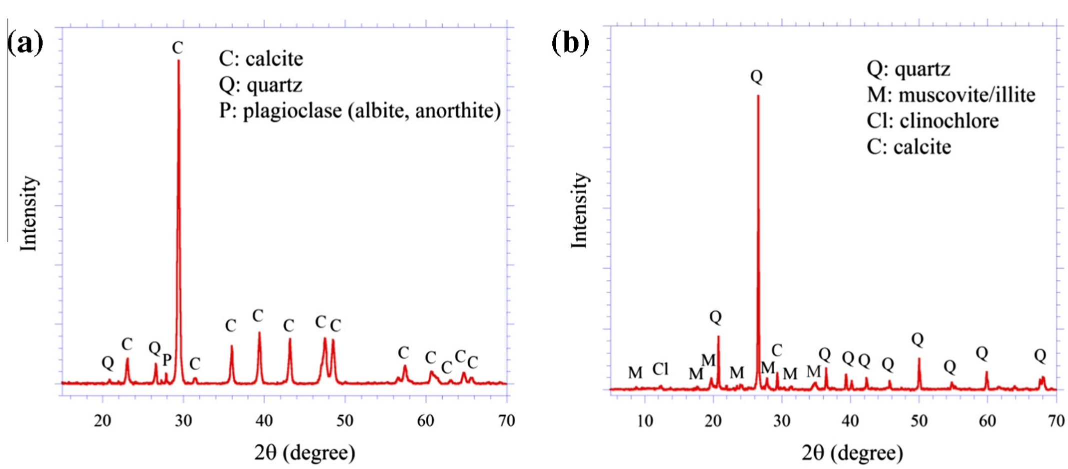

Fig. 1. XRD patterns of (a) waste marble powder and (b) brick clay.