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Physico-mechanical properties and thermal behavior of firebrick-based mortars in superplasticizer presence

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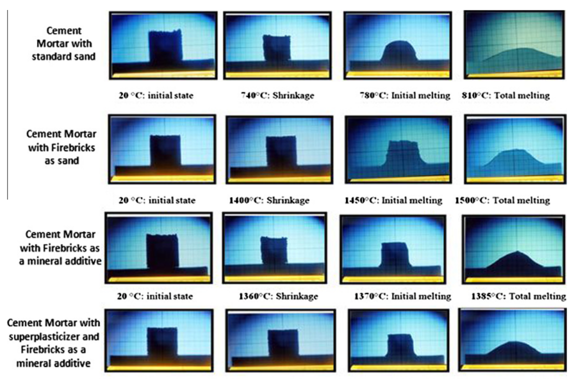
HIGHLIGHTS

- Firebricks wastes in cement mortar production.
- As a sand, firebricks wastes can be used in mortars at a high temperature.
- Effect of firebricks on mortar performance at high temperature.
- Improved behavior at high temperature of cement mortars.

GRAPHICAL ABSTRACT



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ABSTRACT

This study presents the effect of the firebrick wastes with high content of Zirconia (HCZ) as fine aggregates by a total replacement of natural sand and/or by partial replacement of cement, on the physico-mechanical and thermal properties of mortars. An experimental study was conducted out to evaluate physico-mechanical and thermal properties of firebrick-based mortars. The natural sand is totally substituted by the firebrick waste as a fine aggregate and also the cement is partially replaced by the firebrick finely ground. The results show firstly that this waste can be upgraded not only mechanically but also thermally. In fact, the microstructural analysis (heating microscopy, TG–DTA and XRD) show that the use of this waste contributes to the formation of multiple phases (corundum, zirconia, quartz, arnite, syn (Ca_2SiO_4)) whose melting point is considerably higher; this gives the nature of heat-resistant mortars. The introduction of superplasticizer increases in a remarkable way the mechanical strengths compared to normal mortar and waste-based mortars firebricks but is not recommended using superplasticizers at high temperatures. This study allows exploiting these mortars based refractory bricks HCZ up to 1400 °C.
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1. Introduction

Some additions are defined as activator products which, once incorporated into Portland cement, contribute to development the new hydraulic components contributing to the concrete strength. This is due to their chemical–mineralogical composition, some products have hydraulic properties in their own right, setting and hardening under water as the case of the silica fume (SF), ground granulated blast furnace slag (GGBS), fly ash (FA), sedimentary clays (silt of dams). The use of some wastes or by-products has given better results and with successfully, viewpoint mechanical

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Table 1
Characteristics of firebrick wastes.

	Portland cement (PC)	Firebrick (FBW)
Chemical composition (%)		
ZrO_2	–	31.92
SiO_2	24.23	17.06
CaO	60.44	3.36
Na_2O	0.17	2.98
MgO	1.08	1.62
Y_2O_3	–	1.11
HfO_2	–	0.93
Al_2O_3	5.58	39.73
Fe_2O_3	4.09	0.35
SO_3	1.74	0.08
TiO_2	0.24	0.01
P_2O_5	0.07	0.01
WO_3	–	0.01
K_2O	0.95	0.01
Mineralogical composition (%)		
C_3S	53	–
C_2S	22	–
C_3A	06	–
C_4AF	13	–
Physical characteristics		
Specific gravity	3.14	3.69
Specific surface (cm^2/g)	3612	4100
Water absorption (%)	–	2.3
Color	–	Yellow

properties or durability of the material. Several waste types have been cited in the literature as the case of fly ash used to produce Portland cement with additions [1–5], or ground granulated blast furnace slag (GGBS) in concrete [6]. In contrast, other wastes do not possess a hydraulic character but due to their composition which is rich in active silica and aluminum oxide compounds, and their extreme fineness, are capable of fixing calcium hydroxide at normal temperatures and in the presence of water in order to create stable compounds with hydraulic properties. These latter are known as pozzolans. The calcium hydroxide necessary for a pozzolanic reaction can come from free lime or from a hydrating Portland cement.

Recycling of wastes is considered the good solution for their disposal. Indeed, environmental and economic factors increasingly encourage higher utility of industrial waste [5]. The need to develop concrete with non-conventional aggregates rose due to environmental trends as well as economical reasons. As several industrial waste products have properties suited to concrete making, there is large potential to increase the waste recycling by a systematic investigation of the possible use of these wastes in concrete production. However, ceramics product waste found its place in the concrete industry as an additive. Also, ceramic has several positive features such as; it is hard, durable, and has a highly resistant to chemical attacks. Several studies has been investigated the use of firebricks in cement mortars or in concretes. These studies already confirmed the pozzolanic reactivity of ceramic powders [5–7], others have shown that the fluidity has improved and also the mechanical strength (compressive strength and bending strength) are significantly improved in the presence of these powders. It can be cited as an example the silt of dams, glass wastes or the crushed brick [7–13]. It was showed that the silt of dam (CS: calcined silt) has a pozzolanic potential which allows it be used as additive. Safi et al. [14–16] showed that the introduction of 10% CS of self-compacting mortars with of 30% ground granulated blast furnace slag has a positive effect on the rheological behavior and the development of strength. Also, the spent zeolite catalyst was the subject of several studies. Su et al. [17] investigate the use of spent zeolite catalyst as a fine aggregate in cement mortar. The authors found that, the substituted mortars show a best value of compressive strength and the flowability decreases with a spent catalyst presence. It has been noted that crushed firebricks can be used in concrete and it has a best compressive strength than that of control concrete without the use of hollow bricks [18–21]. In view

Table 2
Mixtures details.

Mortar designation	Cement (kg)	Natural sand (kg)	FBW[a] (crushed) (kg)	FBW[b] (finely crushed) (kg)	W/C	SP1 (%)	SP2 (%)
CM	450	1350	0	0	0.50	0	0
M1	450	0	1350	0	0.50	0	0
M2	360	0	1350	90	0.50	0	0
M3	450	0	1350	0	0.35	1.5	0
M4	360	0	1350	90	0.35	1.5	0
M5	450	0	1350	0	0.35	0	2
M6	360	0	1350	90	0.35	0	2

[a] FBW: firebrick wastes (crushed) used as sand.
[b] FBW: firebrick wastes (crushed) used an additive mineral.

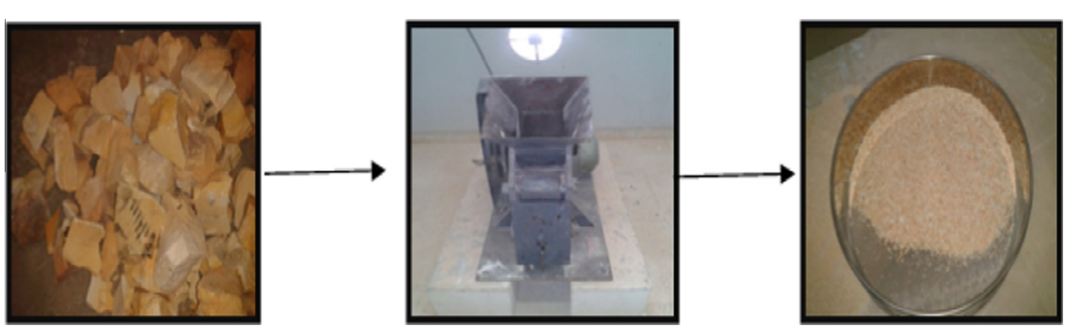

Fig. 1. Preparation steps of crushed firebricks.

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