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Use of refractory bricks as sand replacement in self-compacting mortar

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Abstract: This present work investigate the possibility of using refractory bricks (RB) as fine aggregates (by partial and total substitution of natural sand) in self-compacting mortars (SMCs). For this, an experimental study was carried out to evaluate physical and mechanical properties ((bulk density, compressive and flexural strength) of the self-compacting mortars (SCMs) with partial and total substitution of natural sand (NS) by crushed refractory bricks (RB) at different ratio (BR/S = 0, 10, 30, 50 et 100%) by weight. The results obtained show that the RB (0/5 mm class), can be used as fine aggregates for self-compacting mortar, without affecting the essential properties of mortar. However, the performances of RB-based mortar (100% as sand), were better and are suitable for a fluid concrete (such as self-compacting concrete).

Subjects: Materials Processing; Concrete & Cement; Waste & Recycling

Keywords: refractory bricks; sand; mortar; fluidity; bulk density; compressive strength; tensile strength

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PUBLIC INTEREST STATEMENT

In order to minimize and valorize the Refractory brick wastes (RBW), this work investigate reusing these wastes as a fine aggregate (by sand substitution) in a cement mortar (self-compacting mortar). RBW obtained from glass industry (furnaces) were crushed (0–5 mm granular class) and used in mortar composition. The obtained results show that refractory bricks wastes have a potential to be used in mortars without disrupt the physical and mechanical performance of material. By their valorization, it can protect our natural resources such as natural sand and preserve the environment.

1. Introduction

The growing needs of granular materials and faced to requirements of preservation of the environment, require finding appropriate solutions for a vision of sustainable development. So, it is necessary to prospect and explore all the possibilities and opportunities for reuse and recycling of some wastes the industrial of building products (Binici, 2007; Cachim, 2009; Metha, 2001; Puertas et al., 2008). Concrete material is always be the building material most commonly used and it is one of materials able to using some wastes in different compositions such as a mineral addition or as granulates (Dubey & Banthia, 1998; Edrogdu & Kurbetci, 1998; Lavat, Trezza, & Poggi, 2009; Richard & Cheyrezy, 1995; Vernet, Lukasik, & Prat, 1998; Zeghad, Mitterpach, Safi, Amrane, & Saidi, 2017). Request view of natural aggregates such as natural sand or gravels, especially those, is still in high growing which causes increasing costs due to transport and restrictions on the protection of the environment. For this, it is very interesting to produce in some case concretes with recycled aggregates because it addresses the need for another source of aggregates and reducing the volume of waste. The use of recycled aggregates in concrete has many advantages both in human and economic environmental and technological interests that increasingly industrial. However, ceramics product wastes have been the subject of several research studies in the concrete industry as addition and aggregate. Through some studies have shown that ceramic has several positive features namely reactivity with cement and its effect on the strength of concrete. Zeghad et al. (2017) have carried research work investigated the use of refractories brick wastes in composition of the reinforced high performance concretes. Their results show that, some characteristics of concrete have improved.

Well before, Pašalić, Vučetić, Zorić, Ducman, and Ranogajec (2012) investigated the use of brick wastes in mortar for using as repair mortar of the restoration of ancient buildings. Recently, Saidi, Safi, Bouali, Benmounah, and Samar (2015), were also study investigate the using of refractory ceramic waste as a fine aggregate (by a partial substitution of sand) to produce thermal resistant mortar. In their work have used the refractory brick wastes (with high specific) obtained from local cement industry (furnaces) in mortar by partial substitution of natural sand at different content (0, 10, 20, 30 and 50 wt.%). They have studied the thermal behaviour of these mortars at different cycle (20, 600, 700, 900, 1,010 and 1,100°C for 8 h). The mechanical tests obtained by these authors, have showed that the resistance increases with increase the replacement level (20%) of refractory waste (RBW) by sand substitution. According their study, a non-significant reduction in density was remarked for the specimens with 20% of RBW with the temperature increase. More recent studies have been conducted on the use of bricks in concrete. All these works have leads to same conclusion and that the brick wastes are able being used as a mineral additive or aggregates (González, Gayarre, Pérez, Ros, & López, 2017; Letelier, Tarela, & Moriconi, 2017; Saidi, Safi, Benmounah, Megdoud, & Radi, 2016; Subaşı, Öztürk, & Emiroğlu, 2017).

According to this short bibliography on the using of brick wastes on cement mortars and concretes, it is interesting to see also effect of these waste types on characteristics of fluid mortars in particular the self-compacting mortars. For this, the present study investigate using of refractory ceramic waste (Zirconuim brick type) as a fine aggregate (by partial substitution of sand) to produce self-compacting mortar. Refractory brick wastes (RBW) were crushed at granular classes (0–5 mm) and they are introduced in the mortar by partial substitution of sand at different content (0, 10, 30, 50 and 100% wt.). The fresh (slump test) and hardened (bulk density, flexural and compressive strength) properties of mortars were evaluated.

2. Experimental study

2.1. Materials used for mortars

The materials used in this study were Portland cement (CEM II 42.5), limestone fillers, natural sand NS (0/5 mm), the Refractory Brick Waste (RBW) and a polycarboxylate based superplasticizer. Refractory bricks were recovered from the glass industry in Algeria, after their uses in the oven. Then they suffered preparation processes as sand, namely crushing and sieving (0–5 mm). RBW were

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characterized before being used in mortars composition. Refractory bricks (see Figure 1) used in this work are brick based on silica-zirconium. Table 1 gives also physical properties of two materials used. Figure 2 shows the particle size distribution of used brick. This figure shows the particle size analysis of natural sand and crushed brick waste. According to figure, they have a same fineness. It is also noted that RBW have a non-round shape granulometry can be favoured the adhesion with cementitious matrix.

The chemical composition of RBW used in this work is shown in the histogram form in Figure 3. It is remarkable that zirconium brick contains not only zirconia (40%) but also silica (about 12%). However, this type of brick must have a Zr% more than 30%. Zirconium brick used in this study, is known by their great compactness and having a very low porosity (<1% according to literature) compared to other refractory bricks (microstructural of RBW is shown in Figure 4). According to previously studies, it was noted also that ceramic wastes have an important pozzolanic reactivity (Lavat et al., 2009; Schacht, 1949).

2.2. Composition of studied mortars

The self-compacting mortars (SCMs) were established from a composition of self-compacting concrete by using the design method of concrete equivalent mortar (Safi, Saidi, Aboutaleb, & Maallem, 2013; Schwartzentruber & Catherine, 2000). Table 2 shows the mixes details of control mortar (SCM0) and others variants were obtained by sand substitution by RBW at dosages (0, 10, 30, 50 and 100% wt.). The water–binder ratio used is keep constant (W/B = 0.30) and the fine-cement ratio is also keep constant (F/C = 0.10). The mixing protocol was kept constant for all mortar mixtures.

Figure 1. Refractory brick wastes (RBW).

Figure 2. Chemical composition of RBW.

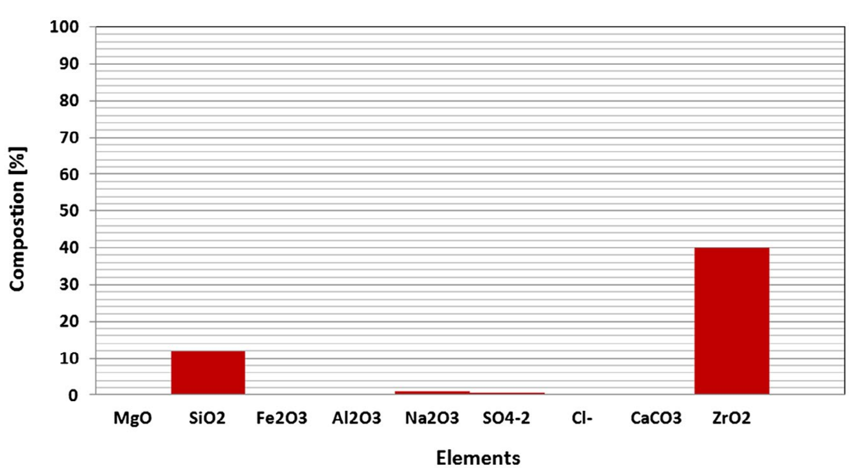


Table 1. The physical properties of natural sand and RBW		
	Natural sand (NS)	Refractory brick wastes (RBW)
Apparent density (kg/m³)	1,520	1,180
Specific gravity (kg/m³)	2,500	2,670
Water absorption (%)	1.03	3.01
Specific surface (m²/kg)	6.24	6.67

Figure 3. Particle size distribution of NS and RBW.

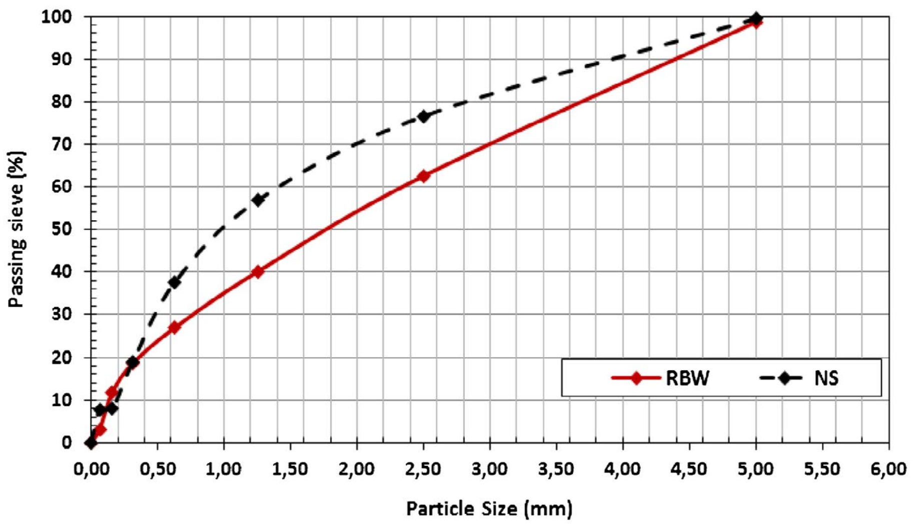
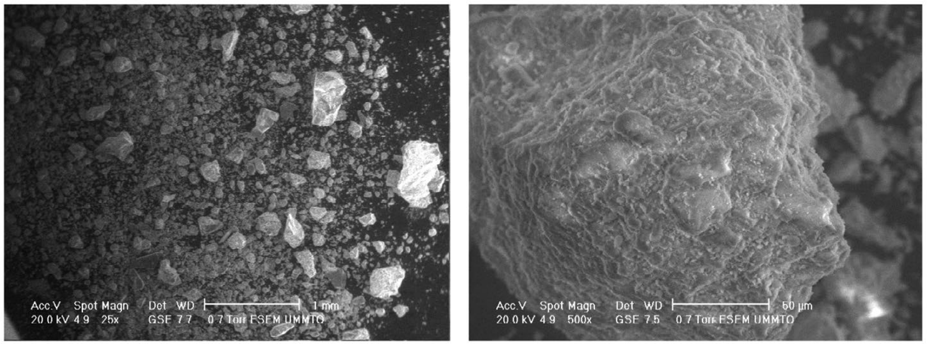


Figure 4. SEM images of RBW.



2.3. Mortar sample preparation and test methods

2.3.1. Fresh properties

After each preparation, the fluidity of the freshly prepared mortar was evaluated to ensure the mini-slump flow diameter suitable for self-compacting concrete according to RFNARC (2002). For hardened properties of mortars, prismatic ($40 \times 40 \times 160$ mm³) samples were manufactured for each mixture. One day after casting, samples were stored in water under 21 ± 1°C.

2.3.2. Hardened properties

The physical (bulk density) and mechanical (bending strength and uniaxial compression) properties of studied mortars were determined. Three-point bending and uniaxial compression tests are carried out at 2, 7, 14 and 28 days on water stored samples. Three-point bending tests were carried out

Table 2. Details of self-compacting mortar mixtures

	Control mortar (SCM0)
Cement [kg/m³]	664
Limestone fillers [kg/m³]	66
Sand [kg/m³]	1,372
Water [kg/m³]	219
Superplasticizer [kg/m³]	9.05
W/B (Water/Binder)	0.30

Notes: SCM0: Mortar control; Natural sand is substituted by RBW at dosages (0, 10, 30, 50 and 100% wt.).

on prismatic samples according to ASTM C348 (2002). Half samples were subjected to compressive stress by using a hydraulic press with a capacity of 3,000 KN according to ASTM C349 (2002).

3. Results and discussion

3.1. Fluidity of mortars

The mortar fluidity was tested by mini-cone and the results are given in Figure 5. According this figure, all studied mortars show fluidity suitable for self-compacting mortars. However compared to SCM0, a decreasing of fluidity of mortars has been recorded with sand substitution by RBW. This can be explained by RBW used have a different shape compared to natural sand (González et al., 2017; Letelier et al., 2017; Saidi et al., 2015, 2016; Subaşı et al., 2017).

3.2. Bulk density and porosity of mortars

Figure 6 shows the evolution of apparent density as a function of sand substitution by RBW at different curing ages (3, 7, 14 and 28 days). It is noted that all studied mortars are same apparent density regardless of curing time. Sand substitution by refractory brick does not a great effect on bulk density of mortar because sand and RBW have almost a same specific mass (Dubey & Banthia, 1998; Edrogdu & Kurbetci, 1998; Pašalić et al., 2012; Saidi et al., 2015, 2016; Vernet et al., 1998; Zeghad et al., 2017).

3.3. Compressive and flexural strength

Evolution of flexural and compressive strength for all studied mortars at different curing age is given in Figure 7. According to results, it is evident that the mechanical strength increases as a function of curing age for all mortars. This is can be explained by cement hydration products. However, the flexural strength decreases slightly depending when RBW is used by sand substitution (Figure 7(a)).

Figure 5. Fluidity of studied mortar.

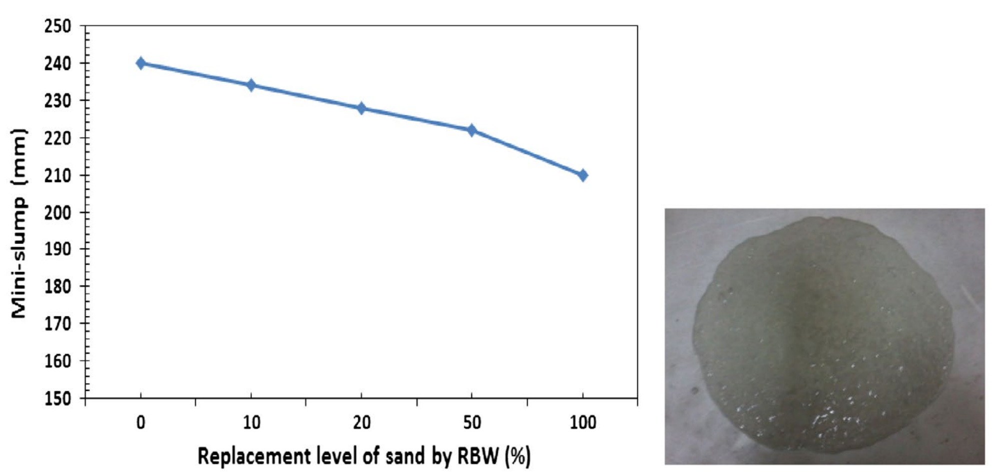


Figure 6. Bulk densities of studied mortars.

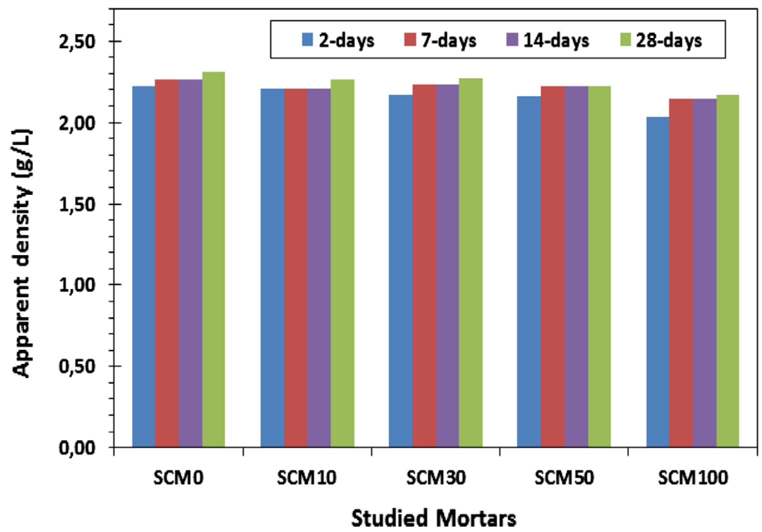
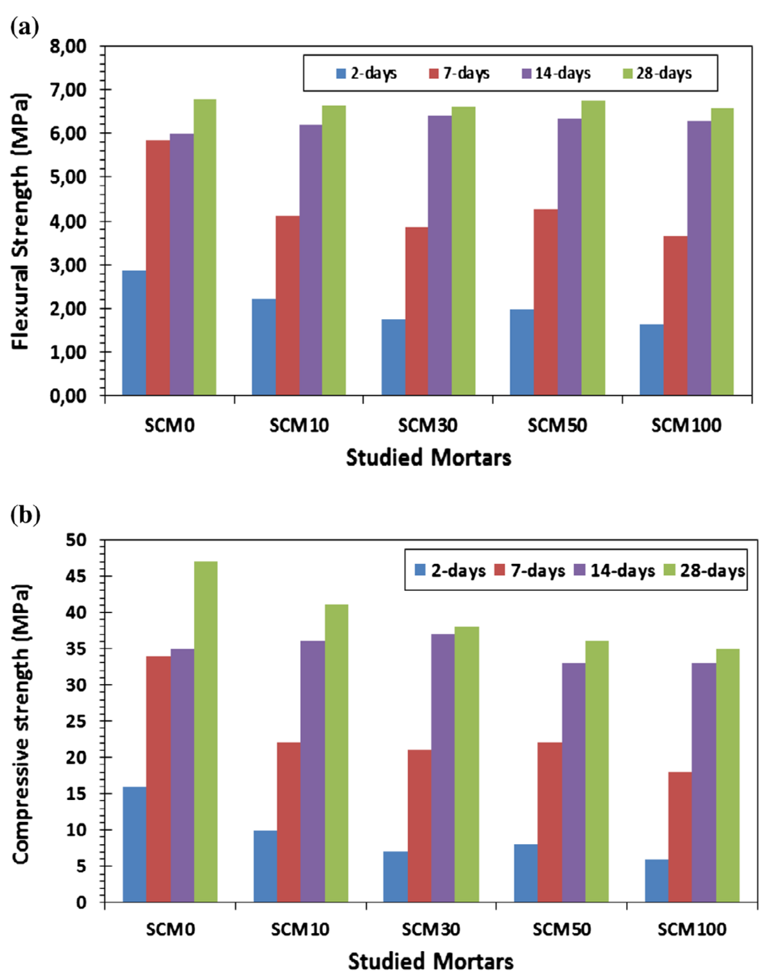


Figure 7. Compressive (a) and flexural (b) strength of all studied mortars.



By against, the compressive strength is decreased with sand substitution at whatever of curing age (Figure 7(a)). It should be also noted that this strength reduction is slight compared to reference mortar SCM0. A mortar containing 100% RBW can give a compressive strength of 35 MPa, compared to the natural sand mortar which has strength of 46 MPa (González et al., 2017; Pašalić et al., 2012; Saidi et al., 2016; Zeghad et al., 2017).

4. Conclusion

The aim of study was use and recycling of refractory brick wastes in the formulation of self-compacting mortars as a fine aggregate by sand substitution (partial or total). An experimental study was carried out to assess the fresh and hardened properties of self-compacting mortars (SCMs) with sand substitution by refractory brick wastes at different ratios (0, 10, 30, 50 and 100% wt.). It can be concluded that;

- Sand substitution of by RBW slightly reduced the fluidity of self-compacting mortars. However, the fluidity recorded for mortars containing 100% RBW can be improved by addition a few amount of superplasticizer;
- For all curing age, sand substitution by RBW does not a great effect on bulk density of mortar because sand and RBW have almost a same specific mass.

The values of flexural strength of mortars are same and does not influenced with sand substitution. At 100% sand substitution by RBW gave a mortar having flexural strength of 7 MPa.

Up to 100% replacement of sand by RBW has caused a slight reduction in the compressive strength. The resistance of RBW-based mortars (100% RBW) is 35 MPa and it is suitable for construction.

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