

🔆 cogent engineering

Cogent Engineering



ISSN: (Print) 2331-1916 (Online) Journal homepage: https://www.tandfonline.com/loi/oaen20

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

Djamila Aboutaleb, Brahim Safi, Kahina Chahour & Amrane Belaid |

To cite this article: Djamila Aboutaleb, Brahim Safi, Kahina Chahour & Amrane Belaid | (2017) Use of refractory bricks as sand replacement in self-compacting mortar, Cogent Engineering, 4:1, 1360235

To link to this article: https://doi.org/10.1080/23311916.2017.1360235

© 2017 The Author(s). This open access article is distributed under a Creative Commons Attribution (CC-BY) 4.0 license



0

Published online: 04 Aug 2017.

- C	
	CT .
. L	

Submit your article to this journal 🗹

Article views: 827



🜔 View related articles 🗹

View Crossmark data 🗹



Received: 15 May 2017 Accepted: 24 July 2017 First Published: 28 July 2017

*Corresponding author: Brahim Safi, Research Units: Materials, Processes and Environment, M'Hamed Bougara University of Boumerdes, Algeria E-mail: safi_b73@univ-boumerdes.dz

Reviewing editor: Paolo Zampieri, Universita degli Studi di Padova, Italy

Additional information is available at the end of the article

CIVIL & ENVIRONMENTAL ENGINEERING | RESEARCH ARTICLE Use of refractory bricks as sand replacement in self-compacting mortar

Djamila Aboutaleb¹, Brahim Safi^{1*}, Kahina Chahour² and Amrane Belaid³

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



Brahim Safi

ABOUT THE AUTHORS

Brahim Safi is a lecturer at University M'hamed Bougara of Boumerdes. He is head of research team Waste Valorization and recycling at research unit; materials, processes and environment. Dr Safi is a member of Editorial Team; *Journal of Building Materials*.

Djamila Aboutaleb is a lecturer at University M'hamed Bougara of Boumerdes, materials engineering department. Dr Aboutaleb is team member of research; Advanced Materials, Glass and Sol-Gel Materials/Research Unit; Materials, Processes and Environment (UR-MPE). Also, she is editorial member: Journal of Metallurgical and Materials Engineering Research (JMMER).

Kahina Chahour, lecturer at University Mouloud Mammeri of Tizi-Ouzou-Civil Engineering Department. She is editorial member of International Journal of Civil, Structural, Environmental and Infrastructure Engineering Research and Development. She is also team member of research; Waste Valorization and Recycling at research unit; materials, processes and environment.

Amrane Belaid is a lecturer at University of Bouira (Department of Civil Engineering). He is team member of research; Waste Valorization and Recycling at Research Unit; Materials, Processes and Environment.

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.

🔆 cogent

engineering





 \circledast 2017 The Author(s). This open access article is distributed under a Creative Commons Attribution (CC-BY) 4.0 license.

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; Subaşi, 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

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.







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 minislump flow diameter suitable for self-compacting concrete according to RFNARC (2002). For hardened properties of mortars, prismatic ($40 \times 40 \times 160 \text{ mm}^3$) 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/m ³]	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 SCMO, 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.

Funding

The authors received no direct funding for this research.

Author details

Djamila Aboutaleb¹ E-mail: issamibrahim3015@gmail.com Brahim Safi¹ E-mail: safi_b73@univ-boumerdes.dz ORCID ID: http://orcid.org/0000-0003-2565-8135 Kahina Chahour² E-mail: chahour.k2017@gmail.com Amrane Belaid³

E-mail: am belaid@yahoo.fr

- ¹ Research Units: Materials, Processes and Environment, M'Hamed Bougara University of Boumerdes, Boumerdes, Algeria.
- ² Civil Engineering Department, Mouloud Mammeri University of Tizi-Ouzou, Tizi-Ouzou, Algeria.
- ³ Civil Engineering Department, University of Bouira, Bouira, Algeria.

Citation information

Cite this article as: Use of refractory bricks as sand replacement in self-compacting mortar, Djamila Aboutaleb, Brahim Safi, Kahina Chahour & Amrane Belaid, *Cogent Engineering* (2017), 4: 1360235.

References

- ASTM C348–08. (2002). Standard test method for flexural strength of hydraulic-cement mortars, which appears in the annual book of ASTM standards vol 04.01.
- ASTM C349–08. (2002). Standard test method for compressive strength of hydraulic-cement mortars (Using portions of prisms broken in Flexure), which appears in the annual book of ASTM standards vol 04.01.
- Binici, H. (2007). Effect of crushed ceramic and basaltic pumice as fine aggregates on concrete mortar properties.

Construct Build Mater, 21, 1191–1197. doi:10.1016/j. conbuildmat.2006.06.002

- Cachim, P. (2009). Mechanical properties of brick aggregate concrete. *Construct Build Mater*, 23, 1292–1297. doi:10.1016/j.conbuildmat.2008.07.023
- Dubey, A., & Banthia, N. (1998). Influence of high-reactivity metakaolin and silica fume on the flexural toughness of high-performance steel fiber-reinforced concrete. ACI Materials Journal, 94, 284–292.
- Edrogdu, S., & Kurbetci, S. (1998). Optimum heat treatment cycle for cement of different type and composition. *Cement and Concrete Research, 28*, 1595–1604. doi:10.1016/S0008-8846(98)00134-3
- EFNARC. (2002, February). Specification and guidelines for self-compacting concrete (pp. 29–35). Retrieved Free pdf copy downloadable from https://www.efnarc.org
- González, J. S., Gayarre, F. L., Pérez, C. L.-C., Ros, P. S., & López, M. A. S. (2017). Influence of recycled brick aggregates on properties of structural concrete for manufacturing precast prestressed beams. *Construction and Building Materials*, 149, 507–514. doi:10.1016/j. conbuildmat.2017.05.180
- Lavat, A., Trezza, M., & Poggi, M. (2009). Characterization of ceramic roof tile wastes as pozzolanic admixture. Waste Manage, 29, 1666–1674. doi:10.1016/j.wasman.2008.10.019
- Letelier, V., Tarela, E., & Moriconi, G. (2017). Mechanical properties of concretes with recycled aggregates and waste brick powder as cement replacement. *Procedia Engineering*, 171, 627–632. doi:10.1016/j.proeng.2017.01.396
- Metha, P. K. (2001, October). Reducing the environment impact of concrete. Concrete can be durable and environmentally friendly. *Concrete International*, 23, 61–66.
- Pašalić, S., Vučetić, S., Zorić, D., Ducman, V., & Ranogajec, J. (2012). Pozzolanic mortars based on waste building materials for the restoration of historical buildings. *Chemical Industry and Chemical Engineering Quarterly*, 18, 147–154. doi:10.2298/CICEQ110829056P

- Puertas, F., Garcia-Diaz, I., Barba, A., Gazulla, M., Palacios, M., & Gomez, M. (2008). Ceramic wastes as alternative raw materials for Portland cement clinker production. *Cement* and Concrete Composites, 30, 798–805. doi:10.1016/j. cemconcomp.2008.06.003
- Richard, P., & Cheyrezy, M. H. (1995). Reactive powder concretes with high ductility and 200–800 MPa compressive strength. *Cement and Concrete Composites*, 25, 1501–1511. doi:10.1016/0008-8846(95)00144-2
- Safi, B., Saidi, M., Aboutaleb, D., & Maallem, M. (2013). The use of plastic waste as fine aggregate in the self-compacting mortars: Effect on physical and mechanical properties. *Construction and Building Materials*, 43, 436–442. doi:10.1016/j.conbuildmat.2013.02.049
- Saidi, M., Safi, B., Bouali, K., Benmounah, A., & Samar, M. (2015). Improved behaviour of mortars at a high temperature by using refractory brick wastes. International Journal of Microstructure and Materials Properties, 10. doi:10.1504/IJMMP.2015.074992
- Saidi, M., Safi, B., Benmounah, A., Megdoud, N.a, & Radi, F. (2016). Physico-mechanical properties and thermal behavior of firebrick-based mortars in superplasticizer

presence. Construction and Building Materials, 104, 311–321. doi:10.1016/j.conbuildmat.2015.12.026

- Schacht, C. A. (1949). Refractories handbook. In C. Augé, & P. Augé (Eds.), *Larousse Universel* (p. 2). Pittsburgh, PA: Schacht Consulting Services.
- Schwartzentruber, A., & Catherine, C. (2000). Method of the concrete equivalent mortar (CEM) - A new tool to design concrete containing admixture. *Materials and Structures*, 33, 475–482. doi:10.1007/BF02480524
- Subaşı, S., Öztürk, H., & Emiroğlu, M. (2017). Utilizing of waste ceramic powders as filler material in self-consolidating concrete. Construction and Building Materials, 149, 567– 574. doi:10.1016/j.conbuildmat.2017.05.180
- Vernet, C., Lukasik, J., & Prat, E. (1998). Nanostructure, porosity, permeability, and diffusivity of Ultra High Performance concrete (UHPC). Symposium international sur les bétons à haute performance et de poudres réactives, Sherbrooke, 3, 17–35.
- Zeghad, M., Mitterpach, J., Safi, B., Amrane, B., & Saidi, M. (2017). Reuse of refractory brick wastes (RBW) as a Supplementary cementitious material in a concrete. *Periodica Polytechnica Civil Engineering*, 61, 81–87. doi:10.3311/PPci.8194



© 2017 The Author(s). This open access article is distributed under a Creative Commons Attribution (CC-BY) 4.0 license. You are free to:

Share — copy and redistribute the material in any medium or format
Adapt — remix, transform, and build upon the material for any purpose, even commercially.
The licensor cannot revoke these freedoms as long as you follow the license terms.
Under the following terms:
Attribution — You must give appropriate credit, provide a link to the license, and indicate if changes were made.
You may do so in any reasonable manner, but not in any way that suggests the licensor endorses you or your use.
No additional restrictions
You may not apply legal terms or technological measures that legally restrict others from doing anything the license permits.

Cogent Engineering (ISSN: 2331-1916) is published by Cogent OA, part of Taylor & Francis Group. Publishing with Cogent OA ensures:

- Immediate, universal access to your article on publication
- High visibility and discoverability via the Cogent OA website as well as Taylor & Francis Online
- Download and citation statistics for your article
- Rapid online publication
- Input from, and dialog with, expert editors and editorial boards
- Retention of full copyright of your article
- Guaranteed legacy preservation of your article
- Discounts and waivers for authors in developing regions

Submit your manuscript to a Cogent OA journal at www.CogentOA.com