

ISSN: 2617-2070 (Print); 2617-2070 (Online)

Journal of Advanced Sciences and Engineering Technologies

Available online at: <a href="https://isnra.net/ojs/index.php/jaset/index">https://isnra.net/ojs/index.php/jaset/index</a>

Journal of Advanced Sciences and Eng. Technologies



#### Mohammed KHATTAB<sup>1</sup> Samya HACHEMI<sup>2</sup> Mohammad Fawzi al Ajlouni<sup>3</sup>

1, 2 LARGHYDE laboratory, Department of Civil Engineering, University Mohamed Khider, Biskra, Algeria.

3 Department of Civil Engineering, Jerash University

 ${\bf 1} \ e\text{-mail}: mohammed.khattab@univ-biskra.dz \ .$ 

2 e-mails : s.hachemi@univ-biskra.dz.

3 e-mail : mohammad-fawzi@engineer.com

## **Keywords**

Recycled, Refractory brick Concrete Wastes

#### ARTICLE INFO

#### Article history:

Received 01.March 2021 Accepted 01.April 2021 Available online 29 June 2021

DOI: http://dx.doi.org/10.32441/jaset.04.01.04 Copyright © 2018 by author(s) and This work is licensed under the Creative Commons Attribution International License (CC BY 4.0). http://creativecommons.org/licenses/by/4.0/





# Recycled Refractory Brick as Aggregate for Eco-friendly Concrete Production

#### **Abstract**

**The** amount of construction and demolition waste continues to increase year by year. These wastes have a significant harmful influence on the environment; refractory brick is among of these wastes. This paper concerns the reuse of refractory brick wastes to produce an eco-friendly concrete. To achieve this objective, Natural Aggregates (NA) (coarse or/ and fine) were partially replaced with recycled Refractory Brick Aggregates (RBA). According to the design of experiment, three families of mixes were prepared and tested: the first mixes was made with coarse and fine NA (as reference concrete), the second mixes made by replacing 20% of coarse NA by coarse RBA and the third mixes was made by replacing 20% of coarse and fine NA by coarse and fine RBA. For each of the mentioned families, three cement dosages of 350 kg/m<sup>3</sup>, 400 kg/m<sup>3</sup>, 450 kg/m<sup>3</sup> were investigated. A series of experiments including water porosity, density and Ultrasonic Pulse Velocity (UPV) and compressive strength were assessed. Observed results indicate that concrete with 20% of coarse and fine RBA had slightly worse performance than reference concrete, but similar or even better than those concretes without using fine RBA.

© 2018 JASET, International Scholars and Researchers Association

#### 1. Introduction

At present, the consumption of concrete has increased proportionately with civilized growth and the increase in the world population, which is causing massive pressure on natural resources. Also, a large amount of concrete waste from demolition and construction is dumped in landfills. From the viewpoint of environmental preservation and protecting natural resources, this situation is a good incentive to recycle and reuse construction and demolition wastes. In recent years, many researchers have evaluated the use of construction and demolition wastes as aggregates in concrete production, which shows that it can be used to replace natural aggregates [1-7]. This research focuses on the important environmental problem of how to deal with refractory brick waste. Refractory brick are mainly used especially within the furnaces basin such as cement. glass and ceramics. A significant number of refractory bricks have served their service life and are being demolished for replacement with new, which results in a large quantity of these wastes, in turn leading to a negative effect on the partial and total substitution of natural sand). The authors found that the refractory brick wastes could be used successfully as a fine aggregate in self-compacting mortars,

environment. In this regard, about 28 million tons of spent refractories waste are generated each year [8]. The use of refractory brick wastes in concrete is an

important step forward to a sustainable construction, thus protecting the environment and saving natural resources, particularly natural aggregate.

However, this waste increasingly has found their place as aggregate (fine or coarse) or as additions material to the manufacturing of concretes or cement mortars. A study has been initiated by Kavas et al. 2006 [9], who investigated the use of magnesiumchromite and alumina based refractory wastes as fine aggregates to produce high temperature resistant mortar. The result obtained by authors show that, properties of magnesium chromite based refractory waste aggregate, have given the best results.Saidi et al. 2015 [10] showed that the introduction of refractory ceramic wastes up to 20% as a fine aggregate on cement mortars has a positive effect on the mechanical tests and development of strength. It has been noted that refractory brick wastes as a fine aggregate have improved the thermal properties of mortars and can be used in applications requiring high temperatures [11]. In fluid mortars in particular the self-compacting mortars, Aboutaleb et al.2017 [12] investigate the use of refractory brick in produce selfcompacting mortar as a fine aggregate (by a

without affecting the essential properties of mortar.

In the case of concrete made with refractory brick aggregate, Nematzadeh and Nasiri,

2017 [13] evaluated the behavior of concrete containing recycled refractory brick wastes by partial or total substitution of natural sand at different replacement ratios 0, 25, 50, 75, and 100% at hightemperature (110, 200, 400, 600, 800, and 1000 °C). According to their result, the residual compressive strengths for specimens containing 100% of refractory brick performed better than conventional concretes at higher temperatures. However, Nematzadeh et al, 2018 [14] have carried research work investigated the extent of corrosion of concrete containing fine refractory brick aggregate in acid environment. They found that the performance of concrete containing fine refractory brick aggregate was rather unsatisfactory in the acid environment.

In order to achieve the possibility of using recycled refractory brick as supplementary cementitious material to prepare recycled al, concrete. Zeghad et 2017 [15] researched experimentally to reuse refractory ceramic wastes the composition of the reinforced highperformance concretes as material supplementary cementitious. According to their study, recycled refractory bricks can have a materials cementitious character for the formulation of concrete.

Recently, Khattab and Hachemi [6] have evaluated the performance of concrete with replacement of coarse NA by coarse RBA at 10, 20, 30, 40, 50, 70, and 100%. The RBA came from two different sources. physical found that the mechanical properties of concrete decreased as the incorporation levels of RBA increased. The author Khattab and Hachemi [7] states additionally that, concrete with 20% recycled refractory brick as coarse aggregate has been graded as good quality with acceptable properties.

To summarize, a number of researchers have focused on the properties of concrete and mortars made with RBA as aggregate (coarse or fine) or additions. However, no attention has been directed at studying the performance of concrete made with fine and coarse RBA, it is interesting to investigate the potential of using refractory brick as coarse and fine aggregate to produce concrete.

This study investigated the physical and mechanical properties of concrete specimens prepared with RBA with different characteristics: first. those manufactured by replacing 20% of coarse NA by coarse RBA, second, those manufactured by replacing 20% of coarse and fine NA by coarse and fine RBA.

Concretes produced were compared with the similar conventional concrete that only contains NA (coarse and fine) in terms of water porosity, density, Ultrasonic Pulse Velocity (UPV), and compressive strength.

#### 2. Experimental research program

## 2.1. Materials

#### 2.1.1. Cement

The cement used in this study was Portland cement (CPJ CEM II/A 42.5). The chemical composition and mechanical properties of this cement were measured in the LPCMA laboratory in Biskra, and the results are presented in **table 1**. From the obtained results, it was observed that the maximum compressive strength of this cement achieved by 34 MPa after 28 days, therefore, did not reach the required strength.

**Table 1.** Chemical composition and mechanical properties of cement.

#### Chemical composition of cement (%) CaO 61.40 MgO 1.32 $SiO_2$ 16.79 $SO_3$ 3.33 3.07 K<sub>2</sub>O 0.72 Fe<sub>2</sub>O<sub>3</sub> $Al_2O_3$ 4.54 Na<sub>2</sub>O 0.21 Mechanical properties (MPa) 7 days 28 days days 30.40 Compressive 18.2 35 strength1.39 2.7 Flexural 1 strength

## 2.1.2. Aggregates

For the present research, the crushed stone were used as natural coarse aggregates, mainly constituted of calcareous, their granular class and water absorption are 5/15 mm, 0.22% and 15/25, 0.26%. The siliceous sand was also used as the natural fine aggregate, with the maximum grain size, fineness modulus and water absorption of 5 mm, 2.51 and 0.65 %, respectively.

In this study, recycled Refractory Brick Aggregate (RBA) was employed, and it was sourced from wastes of cement factory after use in the furnace basin. The RBA used in this work were prepared by a two-stage crushing process:

- Primary crushing was performed on the big blocks of refractory bricks using a small jaw crusher to obtain into smaller ones.
- After primary crushing, refractory brick was subjected to a crushing process using a Los Angeles abrasion machine

The RBA was then sieved and separated into two categories: For the first category, coarse RBA their granular class and water absorption are 5/15 mm, 2.88%, and 15/25, 3.53%, see **figure 1.a**. For the second category, fine RBA with maximum grain

size, fineness modulus and water absorption of 5 mm, 2.60 and 4.32 %, respectively, see **figure 1.b. Figure 2** illustrates grain size distribution of natural and recycled refractory brick aggregates according to P 18-560 [16].

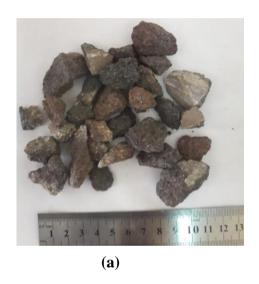




Figure 1. Recycled refractory brick aggregate: (a) coarse (b) fine

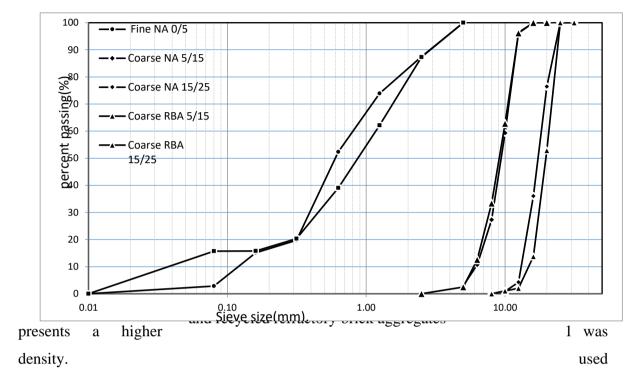
In this research, the physical properties of the natural and recycled aggregates were according tested. to the following standards: NF P 18-554 [17], NF P 18-555 [18], NF P 18-573 [19], NF P 18-598 [20], and the main results are listed in table2. Moreover, a Scanning Electron Microscopy (SEM) was used to observe the microstructure of RBA, and the results obtained are shown in **figure** while **figure3-b** gives the detail of the chemical composition performed by EDX.

As given in **table 2**, the abrasion resistance of coarse RBA is 93% lower than the coarse NA, while water absorption of coarse and fine RBA is about 13 times and 6 times more than for coarse and fine NA, respectively, which leads to much higher porosity as given table 2.

Table 2. Results of the physical tests of the natural and recycled refractory brick aggregates.

Furthermore, the coarse and fine RBA, by comparison with the coarse and fine NA,

A superplasticizer (GLENIUM® 27) with a density is  $1.05 \pm 0.02$  and ph value is  $6.0 \pm$ 



Physical properties	coarse NA		coarse RBA		fine NA	fine RBA
	15/25 mm	5/15 mm	15/25 mm	5/15 mm	0/5 mm	0/5 mm
Apparent density (g/cm³)	1.39	1.43	1.33	1.33	1.55	1.59
Absolute density (g/cm³)	2.70	2.69	2.90	2.90	2.58	3.00
Water absorption (%)	0.26	0.22	3.53	2.88	0.67	4.32
Porosity (%)	1.56	1.16	9.57	9.30	-	-
Water content (%)	0.10	0.11	0.06	0.06	0.08	0.09
Los Angeles abrasion	30		58		-	-
Sand equivalent (%)	-		-		75.8	82.6
Finesse modulus	-		-		2.51	2.60

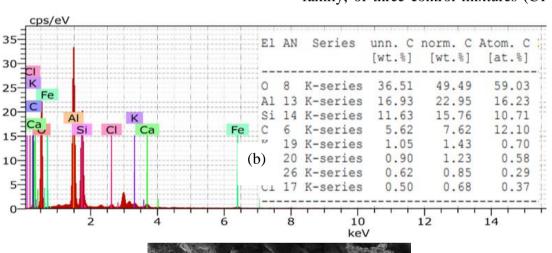
It can be observed that the fineness modulus of fine RBA is comparable with the fine NA. And it also found that the coarse and fine RBA have angular shape and rough surface than the coarse and fine NA, respectively.

to achieve the same workability for concrete with w/c = 0.38 without the additional amount of water. When using a superplasticizer, the dosage was kept constant at 1.4% of the weight of the cement.

## 2.1.3. Superplasticizer

## 2.2 .Design of Concrete Mixtures

Three types of concrete families with dosages of cement of 350, 400, and 450 kg/m3 were made. The details of mix formulations are contained in **Table 3**. As seen in Table 3, each mixture was based on the designation "CA-B", where "C" for concrete, "A" indicates the family No. and "B" indicates cement dosage. The first family, of three control mixtures (C1-350,



Sea 2. Overview.sof, Recycled refractory, brick aggregate

(a)

and C1-450) was manufactured with coarse and fine natural aggregate and they are determined based on the Dreux mix design method [21]. For the second family, three mixtures (C2-350, C2-400, and C2-450) were produced by replacing 20% (by volume) of the coarse NA by coarse RBA. For the third family, three mixtures (C3-350, C3-400, and C3-450) were produced by replacing 20% (by volume) of both

C1-

400,

coarse and fine NA by both coarse and fine

period, a study based on measured the water absorption of coarse RBA each hour was

Mixtur	C	$\mathbf{W}$		w/c		•					Sp
e		Extra	Fine NA	Fine RBA	coarse NA		coarse RBA		(%)		
			water		(mm)	(mm)	(mm)		(mm)		
					0/5	0/5	5/15	15/25	5/15	15/25	
C1-350	350	206.50	-	0.59	688.34	-	226.63	947.84	-	-	-
C1-400	400	190.48	-	0.47	654.83	-	239.88	926.06	-	-	-
C1-450	450	173.08	-	0.82	639.43	-	180.18	958.54	-	-	1.40
C2-350	350	206.50	-	0.59	٦٨٨,٣٤		181.31	758.27	٤٨,٩ ٣	۲۰۳,۸ ۹	-
C2-400	400	190.48	-	0.47	654.83	-	191.91	740.85	51.79	199.20	-
C2-450	450	173.08	-	0.38	639.43	-	144.15	766.83	38.90	206.19	1.40
C3-350	350	206.50	6.95	۰,٥	550.67	160.08	۱۸۱,۳۱	785.27	٤٨,٩ ٣	۲۰۳,۸ ۹	-
C3-400	400	190.48	6.58	0.47	523.86	152.29	191.91	740.85	51.79	199.20	-
C3-450	450	173.08	6.42	0.38	511.54	148.70	144.15	766.83	38.90	206.19	1.4

RBA. The percentage of coarse and fine RBA used was taken from the results of the previous studies [6, 7] and [10], respectively.

It should be pointed that, coarse and fine RBA have a much higher water absorption than that of coarse and fine NA, respectively. Which is important during the process of mixing concrete and we can be overcome of this problem by following methods:

- Extra water is added to the mixture produced with fine RBA, corresponding to the water absorbed by the fine RBA.
- Coarse RBA were immersed in water then air-dried to a saturated dry condition before mixing. To determine the submerging

performed, and results obtained were summarized in **figure 4**. According to **figure 4**, the water absorption of coarse RBA was considered stable after 4 hours of soaking in water.

*Table 3.* Composition of all mixes produced  $(kg/m^3)$ .

## 2.3 Specimen Preparation

For each type of concrete mixture prepared in the previous section, three specimens were cast into cubic steel molds with dimensions 10 cm x 10 cm x 10 cm and duly was compacted by a vibrating table. After 24 h, the concrete specimens were demoulded and then cured ambient underwater at the temperature (20±2°C) for 28 days before they were tested.

## 2.4. Tests on concrete mixes

In order to examine the specimens containing either coarse or both coarse and fine RBA, their some physical and mechanical properties including the water porosity, density, UPV and compressive strength were evaluated.

The density and water porosity of the hardened concrete have been conducted according to the NF EN 12390-7 [22]. The mass of specimens was measured after drying in an electric oven at 60°C ±2°C until reaching a constant mass. Then they were immersed in water until full saturation. After saturation is complete, samples were weighed after remove the surface water by absorbent cloth. In the next step, the mass of the specimens in water was measured by the hydrostatic balance. Three

specimens for each mixture have been tested. Equation (1) and (2) was used to calculate the water porosity (P) and density (D) of concrete specimens, respectively.

$$P = (Mw - Ms) / (Mw - Mw')$$
 (1)  

$$D = Ms / (Mw - Mw')$$
 (2)

Where Ms is the dried mass, Mw is the mass of a specimens measured after full saturation in the air and Mw'is the saturated mass of a specimens measured in the water by the hydrostatic balance.

Moreover, the Ultrasonic pulse velocity (UPV) has been evaluated for estimating the homogeneity of the concrete according to the AFNOR P 18-418 specifications [23]. The value of UPV can be calculated from the path length divided by the measured time. For each mixture, three cubes were tested and the results were averaged.

The ultrasonic pulse velocity is determined according to equation (3):

$$v = L/V (Eq. 3)$$

Where v is the pulse velocity, L is the length of the sample and s is the time.

Finally, the test method specified in NF EN 12390-3 [24] was carried to determine the compressive strength. The test was performed on three cubic specimens of each concrete mixture at the age of 28 days by

using a hydraulic press with a maximum load capacity of 3000 kN. Furthermore, the loading rate of compressive was taken constantly at 0.5 MPa/s for all the specimens according to standard NF EN 12390-4 [25].

## 3. Results and discussion

## 3.1. Water porosity

Results of the water porosity of the various mixes are presented in **figure 5**. As shown in the figure, the water porosity of the concrete mixtures prepared with RBA was higher than the corresponding concrete mixtures prepared with natural aggregate. As stated before, the RBA shows a higher porosity than natural aggregate, which can adversely affect the water porosity of concrete.

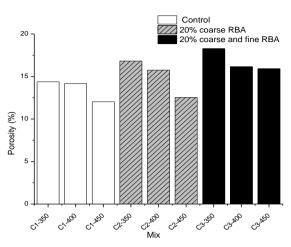
Reference mixtures have a water porosity of 14.37% for C1-350, 14.17% for C1-400, and 12.03% for C1-450. For concretes containing coarse RBA, a slight increase in the water porosity was observed compared to the reference concretes. For instance, mixtures C2-350, C2-400 and C2-450 showed a water porosity of 16.81, 15.74, and 12.53%, respectively; showing an increase of about 17%, 11%, and 4% compared to the reference mixtures. The results also showed that the porosity of concrete is significantly affect when using

coarse and fine RBA. For example, the water porosity of C3-350, C3-400 and C3-450 is 18.27, 16.14 and 15.91%, respectively; yielding an increase of about 27%, 14% and 32% compared to the reference mixtures. This confirms that coarse and fine RBA are more porous than those coarse and fine NA, respectively.

In the tests carried out, it could be observed that increasing the cement content from 350 to 400 and 450 kg/m3 improved the porosity of the concretes prepared of RBA as shown in **figure 5.** This can be explained that increase cement content can transformation of large capillary pores of the concrete, resulting from the inclusion of RBA into smaller ones by fill the voids.

In general terms, the water porosity of concrete with RBA can be controlled by increase cement content and reducing the w /c. Dang and Zhao, 2019 [26] studies indicate, by scanning electron microscopy, recycled brick concrete with a low w/c ratio has satisfactory compactness of Interface Transition Zone.

Figure 5. Water porosity of the studied mixtures.



## 3.2. Concrete density

**Figure 6** outlines the results of all the density tests obtained for different studied mixtures.

The results obtained show that, a slight influence of the RBA inclusion on the density of concrete can be seen; which can be explained by high porosity and water absorption of RBA, which affected the density of concrete.

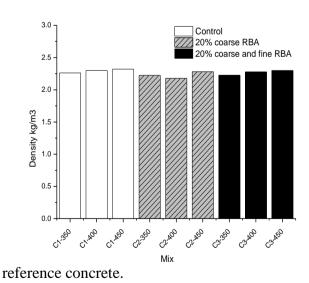
Reference mixtures have a density of 2262, 2299 and 2321 kg/m<sup>3</sup> for C1-350, C1-400, and C1-450, respectively. It can be observed that the density of the concrete mixtures C2-350, C2-400, and C2-450 were 2, 5, and 2%, respectively lower than that for corresponding reference mixtures. However, the inclusion of coarse and fine RBA results in a higher density when compared to concrete prepared with natural

coarse RBA. The density reduction reached 2% for C3-350, 1% for C3-400 and 1% for

C3-450 compared to the reference mixtures C1-350, C1-400, and C1-450, respectively .As can be seen, by incorporating fine RBA in concrete, the density starts to improve and becomes closer to the density of the reference mixtures. This can be attributed to the fact that the fine RBA has a higher density in

comparison with the fine NA (see **table 2**), which can contribute to improving the density of concrete.

As stated above, the density of concrete mixtures prepared with coarse and fine RBA was good and comparable with the

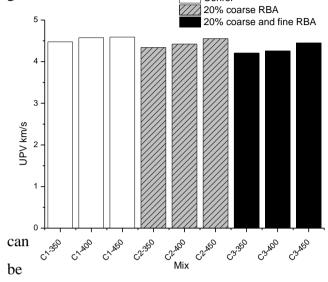


*Figure 6.* Density of the concrete mixes.

## 3.3. Ultrasonic pulse velocity (UPV)

The UPV is used in order to assess the uniformity and quality of concrete as a non-destructive method. Concrete quality classified by UPV value, it is known if the value is above 4.5 km/s the concrete class (excellent), between 3.5 and 4.5 km/s the concrete class (good), between 3.0 and 3.5 km/s the concrete class (medium) and less than 3.0 km/s the concrete class (doubtful) [27]. This property is expected to be affected by the incorporation of RBA, because it depends more on the quality and porosity of the aggregates used. The UPV results of the various specimens are given in **figure 7**.

From the obtained results, the UPV value of the reference mixtures was 4.47, 4.58, and 4.59 km/s for C1-350, C1-400, and C1-400, respectively. As can be seen in the results of the current study, a reduction of the UPV was observed for concrete prepared with RBA, as compared to mixtures prepared with natural aggregate, which can be explained by the high porous structure of RBA. It is showed that, for specimens containing coarse RBA, the UPV reaches a loss of 3 % for C2-350, 3% for C2-400, and 1% for C2-450. Moreover, the use of coarse and fine RBA led to a 6, 7 and 3% reduction in the UPV, respectively for C3-350, C3-400, and C3-450, when compared to concrete prepared with natural aggregate. Considering the concrete prepared with RBA it was found that the UPV values are greater than 3.5 km/s, \_\_\_\_\_\_\_\_\_ which



classified as a good quality concrete.

As shown in **figure 7**, it can be observed the UPV values of concrete prepared with RBA were improved by increasing cement content and decreasing the w/c ratio. This can be explained by reducing the volume of voids in the mixtures due to the increase in cement content, in turn leading to a reduces the time needed to spread the wave through the specimens.

Figure 7. Results of UPV tests.

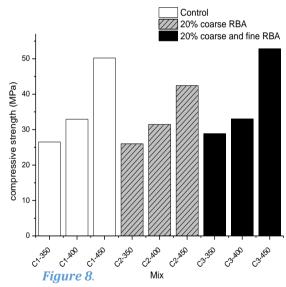
## 3.3. Compressive strength

**Figure 8** shows the test results of the compressive strength of all prepared concrete. In the case of mixtures prepared with coarse RBA, a decreases in compressive strength of concrete was

observed (about 2% for C2-350, 5 %C2-400, and 16% C2-450) compared to concrete prepared with natural aggregates. The decrease in compressive strength is due to several factors: increase in porosity of the paste (caused by coarse RBA with more porous structure) and pre-saturation of coarse RBA. On the other hand, coarse RBA has a lower abrasion resistance than coarse NA, which causes the separation of the external layer of coarse RBA during mixing and transformed to fine aggregate [6,7].

When the coarse and fine RBA is incorporated in the concrete, a slight increase in compressive strength is observed compared to concrete prepared with natural aggregates or coarse RBA. The strength of C3-350, C3-400, and C3-450 were increased by 9, 1, and 5%, respectively, compared to the reference mixtures. One explanation for that may be due to the fact that fine RBA has a density much higher than that fine NA (see table 2) which affect positively the strength of concrete. Another explanation relates to fact that fine RBA has an angular shape and rough surface compared to fine NA, which improves the adhesion of cement paste and creates a good bond between fine RBA and cement pastes. Additionally to those factors, observed that fine RBA does not contain impurities (sand equivalent value 82%); therefore, the use of fine RBA could improve the compressive strength of concrete.

Saidi et al. 2015 [10] also reported the same conclusion; replacing natural fine aggregate with recycled refractory brick improved the compressive strength of cement mortar (for replacement ratios up to 20%). In general, the replacement of the natural fine aggregate by recycled fine aggregate shows a positive or even negligible influence on the mechanical properties of concrete [28,29].



Variation of compressive strength results of concrete mixes.

## 4. General Conclusion

This paper presented an experimental program conducted to study the use of RBA as partial replacements of natural coarse

aggregates or (both fine and coarse) in the production of eco-friendly concrete and the final conclusions of the experimental work are summarized in the following bullets:

- Several physical and mechanical tests of the RBA were performed. These tests detected of RBA are characterized as type of aggregates with higher water absorption, higher porosity, as well as higher mass loss compared to natural aggregate. However, RBA presents a higher density than natural aggregate.
- The use of coarse RBA only does not significantly influence on porosity of concrete. However, when combining coarse and fine RBA in concrete mixes, a significant increase in the porosity of concrete is observed.
- In particular, the mixtures prepared with coarse RBA showed a low density; such a reduction in density is almost negligible in the case of concretes with coarse and fine RBA.
- Not much significant difference is observed in terms of its UPV value, concretes with coarse RBA or both (coarse and fine) show good quality and it generally achieves more than 3.5 km/s at 28 days.

- From a mechanical performance point of view, the replacement of the coarse NA with the coarse RBA would reduce the compressive strength of the concrete. On the other hand, concrete containing coarse and fine RBA showed a slight increase in compressive strength as compared to the corresponding reference mixtures.
- Incorporating either coarse RBA or both (coarse and fine) and lowering the w/c ratio improved the compressive strength, water porosity, density, and UPV. In order to maintain the quality of concrete with recycled refractory brick aggregates, it is necessary to reduce the w/c ratio.

Finally, in spite of the inferior quality of RBA compared to natural aggregate and in general, the RBA as aggregate (coarse and fine) can be used efficiently in the production of eco-friendly concrete.

It can be concluded that concrete made with coarse and fine RBA have a satisfactory performance than concrete with natural aggregate, which might be attributed to the high density of these aggregates. Another research is carrying out for concrete containing coarse and fine RBA at high temperature, it is necessary to understand the performance of this type of concrete when exposed to fire.

Acronyms list: NA- Natural Aggregates;
RBA recycled Refractory Brick
Aggregates; UPV- Ultrasonic Pulse
Velocity; w/c-water to cement (ratio); PPorosity; D- Density; Ms - Mass dried;
Mw- Mass saturated; Mw'- Hydrostatic
balance.

#### **Conflict of Interest**

No potential conflict of interest was reported by the authors.

#### 5. References

- S. Hachemi, Study of the behavior of concrete subjected to high temperature: Influence of the type of concrete and the nature of the constituents, Thesis of science Doctorate in Civil Engineering, University of Biskra, Biskra, 2015.
- S. Hachemi, A. Ounis. Performance of concrete containing crushed brick aggregate exposed to different fire temperatures, European Journal of Environmental and Civil Engineering. 19 (2015) 805-824. <a href="http://dx.doi.org/10.1080/19648189.2014">http://dx.doi.org/10.1080/19648189.2014</a>. 973535.
- Yaragal, S. C., & AK, M. R. (2017). Usage potential of recycled aggregates in mortar and concrete. Advances in Concrete

- *Construction*, *5*(3), 201.
- 4. Hammad Salahuddin , Liaqat Ali Qureshi , Adnan Nawaz , Muhammad Abid 4, Rayed Alyousef , Hisham Alabduljabbar , Fahid Aslam , Summera Fahmi Khan and Rana Faisal Tufail . Elevated Temperature Performance of Reactive Powder Concrete Containing Recycled Fine Aggregates, Materials 2020, 13, 3748. doi:10.3390/ma13173748
- George Dimitriou, Pericles Savva, Michael F. Petrou. Enhancing mechanical and durability properties of recycled aggregate concrete, Construction and Building Materials 158 (2018) 228–235. <a href="https://doi.org/10.1016/j.conbuildmat.2017">https://doi.org/10.1016/j.conbuildmat.2017</a>
   .09.137
- 6. KHATTAB M., HACHEMI S. Performance of concrete made with recycled coarse aggregate from waste refractory brick. Algerian journal of engineering architecture and urbanism. "in press"
- 7. KHATTAB M., HACHEMI S.
  Performance of recycled aggregate
  concrete made with waste refractory brick.
  International Journal of Engineering
  Research in Africa. "in press"
- L. Horckmansa, P. Nielsen, P.e Dierckx, Antoine Ducastel,2019. Recycling of refractory bricks used in basic steelmaking: A review, Resources, Conservation & Recycling 140 (2019) 297–304. <a href="https://doi.org/10.1016/j.resconrec.2018.0">https://doi.org/10.1016/j.resconrec.2018.0</a>
   9.025
- T. Kavas, B. Karasu, O. Arslan, 2006. Utilization of refractory brick wastes in concrete production as aggregates, Sohn International Symposium Advanced Processing of Metals and Materials vol. 5 -New, improved and existing technologies: Iron and steel and recycling and waste treatment, Edited by F. Kongoli and R.G. Reddy TMS (The Minerals, Metals &

- Materials Society), 479-483.
- 10. M. Saidi, B. Safi, K. Bouali, A. Benmounah. M. Samar. **Improved** behaviour of mortars at a high temperature refractory by using wastes, International Journal of Microstructure and Materials Properties. 10 (2015)366-380. https://doi.org/10.1504/IJMMP.2015.0749 92.
- M. Saidi, B. Safi, A. Benmounah, N.Megdoud, F, Radi, J Physico-mechanical properties and thermal behavior of firebrick-based mortars in superplasticizer presence, Construction and Building Materials 104 (2016) 311–321 .http://dx.doi.org/10.1016/j.conbuildmat.2 015.12.026
- D. Aboutaleb, B. Safi, K. Chahour, A. Belaid, 2017. Use of refractory bricks as sand replacement in self-compacting mortar, Cogent Engineering. 4, 1360235. <a href="https://doi.org/10.1080/23311916.2017.13">https://doi.org/10.1080/23311916.2017.13</a>
   60235.
- Nematzadeh, A. Baradaran-Nasiri, 2018. Residual properties of concrete containing recycled refractory brick aggregate at elevated temperatures, Journal of Materials in Civil Engineering. 30, 04017255. <a href="https://doi.org/10.1061/(ASCE)MT.1943-5533.0002125">https://doi.org/10.1061/(ASCE)MT.1943-5533.0002125</a>.
- 14. M. Nematzadeh, J. Dashti, B. Ganjavi, Optimizing compressive behavior of concrete containing fine recycled refractory brick aggregate together with calcium aluminate cement and polyvinyl exposed acidic alcohol fibers to environment, Construction and Building Materials. 164 (2018)837-849. https://doi.org/10.1016/j.conbuildmat.2017 .12.230
- M. Zeghad, J. Mitterpach, B. Safi, B. Amrane, M. Saidi, Reuse of refractory brick wastes (RBW) as a supplementary

- cementitious material in a concrete, Periodica Polytechnica Civil Engineering. 61(2017) 75-80. https://doi.org/10.3311/PPci.8194.
- French standardization P 18-560. (1990).
   Aggregates Particle size distribution by sieving. French Association for Standardization (AFNOR). Tour Europe cedex 7 92049. Paris.
- French standardization P 18-554. (1990).
   Aggregates Measurement of densities, porosity, absorption coefficient and water content of fine gravel and pebbles. French Association for Standardization (AFNOR).
   Tour Europe cedex 7 92049. Paris.
- French standardization P 18-555. (1990).
   Aggregates Measurement of densities, absorption coefficient and water content of sands. French Association for Standardization (AFNOR). Tour Europe cedex 7 92049. Paris.
- French standardization P 18-573. (1990).
   Aggregates Los Angeles test. French Association for Standardization (AFNOR).
   Tour Europe cedex 7 92049. Paris.
- French standardization P 18-598. (1991).
   Aggregates Sand equivalent. French Association for Standardization (AFNOR).
   Tour Europe cedex 7 92049. Paris.
- G. Dreux, J. Festa, New guide to concrete and its constituents, Paris: Edition Eyrolles, 1998.
- 22. European Standard NF EN 12390-7. (2001). Test for hardened concrete Part 7: Density of concrete. ISSN 0335-3931. The French Association of Standardization (AFNOR), 11 avenue Francis de Pressensé 93571 Saint-Denis La Plaine Cedex.
- 23. French standardization P 18-418. (1989). Concrete – Sonic auscultation, measurement of the sonic wave transmission time in concrete. French Association for Standardization (AFNOR). Tour Europe cedex 7 92080. Paris.

- 24. European Standard NF EN 12390-3. (2003). Test for hardened concrete Part 3: Compressive strength of test specimens. ISSN 0335-3931. The French Association of Standardization (AFNOR). 11 avenue Francis de Pressensé France 93571 Saint-Denis La Plaine Cedex.
- 25. European Standard NF EN 12390-4. (2000). Test for hardened concrete Part 4: Characteristics of test machines. ISSN 0335-3931. The French Association of Standardization (AFNOR). 11 avenue Francis de Pressensé France 93571 Saint-Denis La Plaine Cedex.
- 26. J. Dang , J. Zhao , Influence of waste clay bricks as fine aggregate on the mechanical and microstructural properties of concrete, Construction and Building Materials 228 (2019) 116757.
  <a href="https://doi.org/10.1016/j.conbuildmat.2019">https://doi.org/10.1016/j.conbuildmat.2019</a>
  .116757.

- 27. Whitehurst, E. A. (1951). Soniscope tests concrete structures. Journal of the American Concrete Institute, 47, 443–444.
- 28. J. S. González , F.L.Gayarre , C. L. Pérez , P. S.Ros , Miguel A. S. López , Influence of recycled brick aggregates on properties of structural concrete for manufacturing precast prestressed beams, Construction and Building Materials 149 (2017) 507–514.

https://doi.org/10.1016/j.conbuildmat.2017 .05.147

29. A.V. Alves , T.F. Vieira , J. de Brito , J.R. Correia , Mechanical properties of structural concrete with fine recycled ceramic aggregates, Construction and Building Materials 64 (2014) 103–113. <a href="https://doi.org/10.1016/j.conbuildmat.2014">https://doi.org/10.1016/j.conbuildmat.2014</a> .04.037.