Multi-criteria study for recycled concrete aggregate separation process

Sandrine Braymand[1], Sébastien Roux[2], Hanaa Fares[3], Françoise Feugeas[4]

[1] ICube, Strasbourg Univ., CNRS, 72 Route du Rhin, Illkirch, France,
Phone (+33) 368 85 85 08, E-Mail: s.braymand@unistra.fr
[2] IJL, Lorraine Univ., CNRS, Rue du Doyen Urion, Villers lès Nancy, France,
E-Mail: sebastien.roux@univ-lorraine.fr
[3] L2MGC, 5 mail Gay-Lussac, Cergy Pontoise Univ., Neuville-sur-Oise,
E-Mail: France,hfares@u-cergy.fr
[4] ICube, INSA Strasbourg, CNRS, 24 bd de la Victoire, Strasbourg, France,
E-Mail: francoise.feugeas@insa-strasbourg.fr

Abstract

Construction and demolition waste stream has generated news materials that may be re-introduced into new concrete, e.g. as recycled aggregates. The specific feature of recycled concrete aggregates (RCA) is the presence of hardened mortars influencing their behaviour. This study aims to distinguish processes that allow the complete separation and quantification of attached mortar. The laboratory developed method has to be transferable on a wider scale to be exploited on a real recycling platform. This study is linked to the RECYBETON National Research Project involving public research laboratories, institutes and private companies.
Several methods are tested in laboratory conditions to determine their efficiency. They are based on mechanical, chemical and physical principles. The definition of this efficiency concept and the mortar content denomination are also discussed.
Originality of this study consists in optimizing hot or cold thermal processes combined with a mechanical treatment. To perform that, a multi-criteria phase experiment was carried out and several values of the multi-criteria parameters were optimized. Results allow for a thorough knowledge of treatment efficiency. However, it appears that not any one method is 100% satisfactory as aggregates are never completely cleaned and/or are damaged.

Keywords: Recycled concrete aggregates, attached mortar, separation, process.

Introduction

The presence of primary mortar in recycled concrete aggregate (RCA) is responsible for the different behaviour of these aggregates and natural aggregates [BRA 16]. It influences the composition of concrete in which RCA could be introduced [DEO 15, DEJ 09]. A solution is to pre-treat on the recycling platform RCA in the aim of re-obtaining aggregates without mortar. This study aims firstly to select and to experiment processes leading to a highest separation, and secondly to propose an in-depth study on the real efficiency of treatments.

Experimental Methods and Results

First, some methods are tested in the laboratory: mechanical wear, sandblasting, micro-waves, acid and thermal treatments (Figure 1).

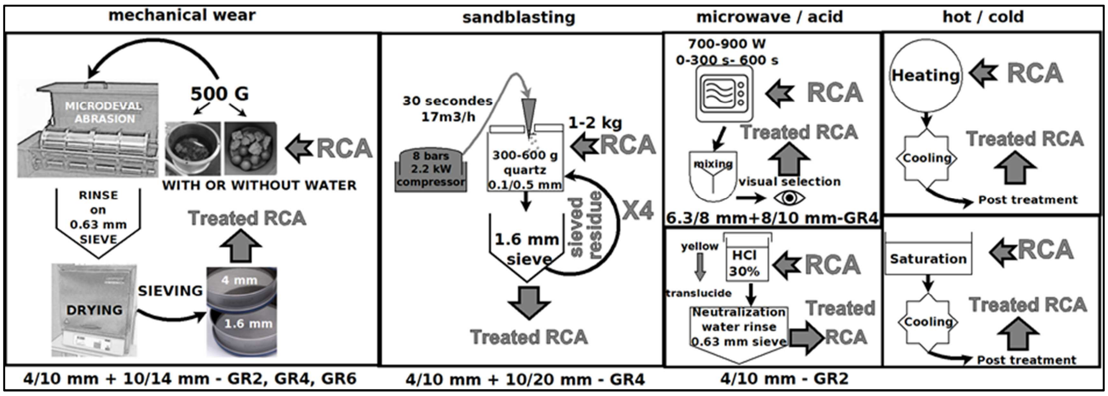

Figure 1. Separation processes tested in the laboratory.

Processes efficiency is analyzed using mass loss measurement, density variation and visual comparison. In most of the studies presented in the literature, efficiency is only correlated to mass loss which is directly linked to the separation of mortar from primary aggregates [TOR 13,YOD 03,FLO 14, AKB 13]. However, a high mass loss does not always mean that the process is efficient, it is necessary to control the properties of the treated aggregates before concluding, especially their density and water absorption. Without knowledge of the primary aggregates properties, it is quite difficult to conclude about the separation rate and a visual check is necessary.

This exploratory study indicates that, among treatments identified as efficient, thermo-mechanical treatments are the most easily transferable to industrial scale. Also, they are not harmful to health or environment. High or low temperature treatments lead to a first degradation of mortar. Then it can be separated from primary aggregates with a mechanical post-treatment

Then, multi-parameter study of thermo-mechanical methods is carried out (Figure 2 and Figure 3) and several values of parameters are optimized.

Concerning high temperature heat treatment, a temperature of 600°C is required to decompose constituents such as CSH and portlandite [FAR 10]. However, this temperature leads to damage the aggregates in the case of the calcareous natural aggregates. In the case of low temperature heat treatment, industrial conditions limit the value of the low temperature (not lower than -10°C) and the duration of the freeze/thaw cycles (not longer than 4 days). These conditions limit its effectiveness. It has been shown that saturation and immersion of the material favors mortar damage by internal and external pressure of water during temperature cycles.

Analyze of the efficiency criteria indicates that to obtain a cleaned aggregate, a "manual" sorting is necessary to complete the sorting by sieving. Indeed, it has been found that the mortar, even if it is detached from the primary aggregate, is not completely crushed and remains mixed with the treated aggregate. This manual sorting could be transferable at an industrial scale by optical visual sorting equipment, but it increases cost of the process.

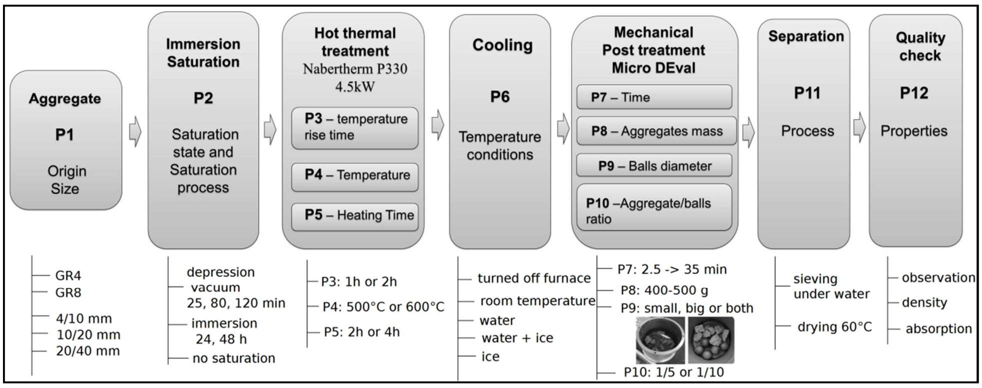

Figure 2. High temperature thermal-mechanical processes and their parameters.

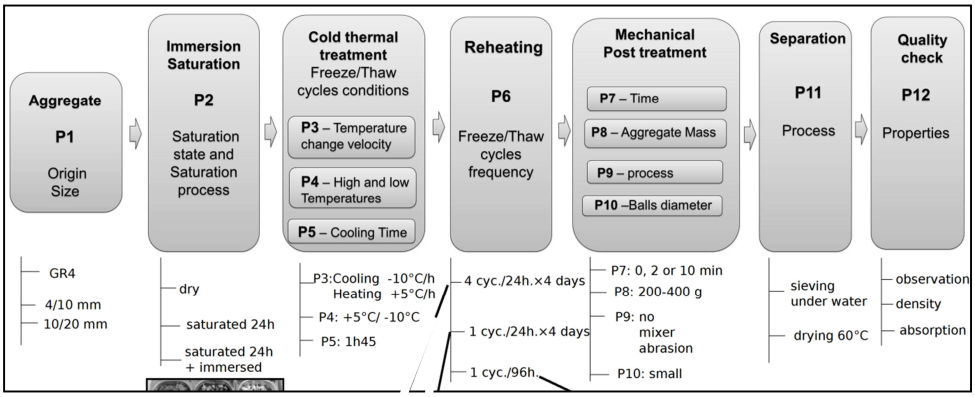

Figure 3. Low temperature thermal-mechanical processes and their parameters.

The definition of efficiency must be extended to this visual check or to density properties of treated aggregates (as Table 1) and must be characterized by the proportion of material cleaned and undamaged. Indeed, mass reduction and density are not correlated (Figure 4). Finally, the efficiency of the treatments remains low since, for 1 tons of material to be processed only 130 kg are clean and undamaged for the low temperature thermo-mechanical process, and 240 kg are clean and undamaged for the high temperature thermo-mechanical process. For the latter, the densities of the parent aggregates are found, contrary to the cleaned but damaged aggregates (Table 1).

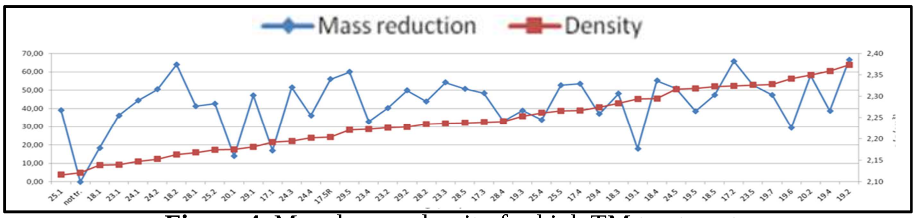

Figure 4. Mass loss vs density for high TM treatments

Table 1: Control of aggregates after high temperature TM process

Aggregate	Density	Porosity	Absorption
Clean and undamaged	2,72 g/cm^3	2,70%	0,99%
Clean and damaged	2,35 g/cm^3	2,41 %	5,67%
Partially cleaned	2,39 g/cm^3	8,21%	3,43%
Mortar	2,09 g/cm^3	17,67%	8,46%
Untreated aggregate	2,25 g/cm^3	12%	6%
Initial 4- 20 mm concrete aggregate	2,55 g/cm^3	1%	0,75%

Conclusion

Among the studied processes, thermo-mechanical processes make it possible to obtain a cleaned and undamaged aggregate, but the production efficiencies are low and, depending on the nature of the aggregate, the damage may be inevitable. Thus, it appears that no method is 100% satisfactory because the aggregates are never completely cleaned and / or are damaged.
At the end of this study, which contains numerous experimental results, it has been shown that few processes for cleaning recycled aggregates can be transposed on an industrial scale at reasonable environmental and economic cost if a very good cleaned aggregate is attempted.

References

[BRA 16] Braymand S., Roux, S., Deodonne K, Fares H., Feugeas F., Separation and quantification of attached mortar in recycled concrete aggregates. Waste and biomass val., 2017, in press.

[DEO 15] Deodonne K., Étude des propriétés physicochimiques des bétons de granulat recyclés et de leur impact environnemental, PhD thesis, Strasbourg Univ, 2015.

[DEJ 09] De Juan M.S., Gutiérrez P.A.: Study on the influence of attached mortar content on the properties of recycled concrete aggregate, Constr. Build. Mater., Vol. 23, 2009, p. 872–877.

[TOR 13] Torgal F.P., Handbook of recycled concrete and demolition waste, Cambridge Ed. 2013.

[YOD 03] Yoda K., Harada M, Sakuramoto F, Field application and advantage of concrete recycled in-situ Recycling Systems, Thomas Telford Serv. Ltd., 2003, p. 437–446.

[FLO 14] Florea M.V.A, Ninig Z., Browers H.J.H., Smart crushing of concrete and activation of liberated concrete fines, TU/e. Final report, 2014.

[AKB 13] Akbarnezhad A., Ong K.C.G.: Separation processes to improve the quality of recycled concrete aggregates (RCA), In: Handbook of Recycled Concrete and Demolition Waste, 2013,p. 246–269

[FAR 10] Fares, H., Remond, S., Noumouwe, A., Coustuer, A. High temperature behaviour of self-consolidating concrete: Microstructure and physicochemical properties, Cem. Concr. Res., vol. 40, 2010, p. 488–496.