Mixing recycled aggregates concrete – old methods for new concrete

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Abstract

There have been a great number of laboratory studies on mixing approach for recycled aggregate concrete (RAC) even if in practice, the simplest procedures are generally employed. Some of these methods give good results comparing with the traditional mixing method.

The present paper resume some main mixing methods proposed in the literature, specifically for RAC. The two-stage mixing approach (TSMA) splitting the required water into two parts in divers proportions, is a development of the previously Japanese proposed sand enveloped with cement (SEC) mixing method. Other methods were proposed, like for instance the sand enveloped mixing approach (SEMA) or the loading of (recycled) aggregates into a pre-processed mortar or paste (cement paste encapsulating aggregate method). This short literature review also discusses the effect of the initial moisture of the RCA and the concept of effective water which seems still valid for RAC.

It is not clarified today the extent to which the improvements resulted from alternative mixing methods are specific to the RAC mixing, or are more general phenomena. In the light of recent works, two points are underlined here. First, the quantity of water absorbed by the aggregates depends of factors not sufficiently elucidated yet. For instance, the pre-wetting method potentially could conduct to different RCA water absorption after mixing. Second, the mechanical benefits of the hardened RAC produced by TSMA it is classically explained by an increase of the ITZ strength. We consider that a complementary explanation should be looked in the higher attrition of the RCA produced by TSMA. This phenomenon is supposed to induce better compacity of the mixture and higher quality of the RCA.

Keywords: mixing method, two-stage mixing, effective water.

Introduction

It is generally admitted that the RCA high level of water absorption [1] [2] and heterogeneity [3] generates difficulties in the correct water proportioning from one batch to another. Also, the water absorbed between end of mixing and casting can change the consistency of the concrete during transport. Belin et al. [4] expect that workability loss due to water absorption should be different from one RCA to another. They also discussed that the water absorption kinetics of RCA could be different in pure water or when they are immersed in a cement paste. Indeed, the work of Bello [5] showed that the water absorption kinetics of light aggregates immersed in a cement paste strongly depended on the water to powder ratio of the paste.

The mortar content also lowers the strength of the aggregates. For instance, Barbudo [6] observed a typical ratio of 2 between the Los Angeles’ values of RCA and natural aggregates. After a study of the influence of barite aggregate friability on mixing process [7], Moreno Juez et al. [8] demonstrated that attrition and cleavage mechanisms could produce significant grading evolution of RCA during the mixing.
This paper resumes some aspects of mixing methods proposed in the literature to improve the quality of mixing of recycled aggregate in new concrete. Coating and some pioneering data on the results of two emerging mixing technologies applied on recycled aggregate concrete – vibratory mixing and mixing under vacuum – are not considered in this brief survey.

Initial moisture of RCA

A first level of questions aroused about the influence of the initial moisture of the RCA on the RAC concrete mixing result. In order to avoid problems on the consistency of the RCA, Gonzalez et al. [9] proposed immersing the aggregates in water for 10 minutes and the other, with eventually a brief air drying and subsequent elimination of surface water from the aggregate. The complete saturation in order to stop any water transfer into the aggregates had already been proposed by some authors previously [10]. Barra and Vazquez [11] and Poon et al. [12] analyzed the effect of oven drying, air drying or completely saturating surface-dry RCA before mixing. They conclude that air dried RCA gave improved workability and compressive strength of the concrete as after oven drying or saturated surface-dry conditions. The authors suggested that saturation point should not be reached because of the risk of bleeding. However, for recycled fine aggregates obtained from concrete, Ji et al. [13] obtained that the cracking resistibility of the concrete increases with the initial moisture of the aggregates, from oven dried to saturated surface dry.

At evidence, the use of differently moistened RCA by keeping the added water constant (so with different total water content) conducts to an increase in workability and a decrease of the compressive strength for the more wetted aggregates [14] [15]. Indeed, the concept of effective water [16] seems still valid for the RAC [17]. Mefteh et al. [14] also studied the slump loss for recycled concrete aggregates at oven dry, saturated surface-dry and intermediary pre-wetted conditions, maintaining the added water constant. The slump loss do not seemed influenced by the initial moisture of the aggregates (or consequently by the initial slump value). In fact, the slump loss was similar that those of the concrete produced with natural aggregates. This result could be interpreted as the effect of a fast absorption of the RCA from this study, which probably mostly occurs during the mixing time as suggested by Salgues et al. [18]. However, Khoury et al. [19] demonstrated that the pre-wetting history of the RCA – long-term or short-term – could change the amount of the water absorbed by the RCA with as much as 1% of their mass and could significantly change the real effective water into the mixture.

Mixing procedure

The sand enveloped with cement (SEC) concrete mixing procedure was proposed in the early 1980’s as a method to improve the compressive strength of the normal concrete (using natural aggregates) [20] [21]. In the procedure the water was added into the mixer at two separate times: the first water addition was fixed to 25% by weight of the cement, including any surface moisture of the sand and gravel. The method yielded up to 25% of compressive strength increase as compared to normal mixing method (one stage mixing).

In the late 1990’, it was observed that the process for recycled aggregate to absorb a part of mixing water before mixing or during mixing process is effective to achieve higher strength of concrete [23]. Consequently, the SEC method was adapted to the specificity of the recycled aggregates, by increasing the amount of the first part of water to 50% and by delaying the introduction of the cement after the loading of this first amount of water [24] [25]. This double-mixing method improved the mechanical behavior (compressive strength with about 15%, tensile strength with about 20 – 25%) and the durability (chloride...
penetration and carbonation resistances) of RAC compared with normal single stage mixing. The mixing method, termed TSMA (two stage mixing approach) [27] was more deeply studied in the recent years. And it was showed an increasing beneficial effect with the RCA replacement level [28]. Increased compressive strength and durability properties (water absorption, sorptivity, chloride ion penetration, drying shrinkage, and abrasion resistance) for high-strength concrete were confirmed [29] but with no effect on the frost resistance of air-entrained RAC [31]. Brand et al. [32] shown that TSMA is more effective in the increase of the mechanical properties of the RAC if the RCA are partially-saturated, as opposite to their use oven dried or saturated. At opposite, adverse effects like strength reduction were obtained for concrete using fine recycled aggregates [29].

The beneficial effect of the two-stage mixing method was explained by an improving of the properties of the new ITZ in the RAC when two-stage mixing is used [25] [26]. Indeed, this was already demonstrated for the SEC method using natural aggregates [22]. However, a complementary explanation should be taken into account: the increase of the fine content due to significant attrition of the RCA during mixing [8]. These authors demonstrated that the fine created during mixing RCA without cement is significantly higher than the attrition during mixing concrete composition. Or TSMA procedure adds important mixing time of RCA without cement.

Several researches presented other mixing procedures for RAC. The cement paste encapsulating aggregate method (first mixing the cement paste than incorporating coarse aggregates and sand) had intermediate mechanical effect on the RAC between the normal mixing and the TSMA [31]. The sand enveloped mixing approach (SEMA) gave better results than the TSMA in terms of compressive strength of secondary concrete. The SEMA mixes sand, cement, and 3/4 of the total water before the addition of recycled aggregate, allowing the sand particles to mix more readily with the cement and water and thus less water will be absorbed by the recycled aggregate [33].

**Conclusion**

It is not clarified today the extent to which the improvements resulted from alternative mixing methods are specific to the RAC mixing, or are more general phenomena.

Two points are discussed here in the light of recent works. First, the concept of effective water seems still valid for RAC but the quantity of water absorbed by the aggregates depends of factors not sufficiently elucidated yet. For instance, the pre-wetting method potentially could conduct to different RCA water absorption after mixing.

Second, the TSMA produce higher compression strength concrete mixing method by an increase of the ITZ strength. The mechanical benefits of the hardened RAC should be complementary by explained by other phenomena. For instance, TSMA is supposed to produce higher attrition of the RCA, inducing better compacity of the mixture and higher quality of the recycled concrete aggregate.

**References**


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