Construction and Building Materials 64 (2014) 172–183

Contents lists available at ScienceDirect

Construction and Building Materials

journal homepage: www.elsevier.com/locate/conbuildmat

Effect of surface treatment methods on the properties of self-compacting concrete with recycled aggregates

Erhan Güneyisi [a,*], Mehmet Gesoğlu [a], Zeynep Algın [b], Halit Yazıcı [c]

[a] Department of Civil Engineering, Gaziantep University, 27310 Gaziantep, Turkey
[b] Department of Civil Engineering, Harran University, 63000 Şanlıurfa, Turkey
[c] Department of Civil Engineering, Dokuz Eylül University, 35160 İzmir, Turkey

HIGHLIGHTS

- We studied use of recycled concrete aggregate (RCA) in self-compacting concrete (SCC).
- Treatment methods were applied on RCA used in SCC.
- Effect of treatment methods on engineering properties of SCC was investigated.
- Microstructures of treated RCA and produced SCC were examined.
- Treatment methods remarkably affect self-compactibility characteristics of concrete.

ARTICLE INFO

Article history:
Received 20 February 2014
Received in revised form 4 April 2014
Accepted 9 April 2014
Available online 4 May 2014

Keywords:
Fresh property
Microstructure
Recycled aggregate
Self-compacting concrete
Strength
Treatment method

ABSTRACT

In this experimental study, the adverse effect of old cement-mortar composite on self-compacting concrete (SCC) containing recycled concrete aggregate (RCA) were investigated by means of potential aggregate treatment methods so as to promote the maximum RCA utilisation. Although the limited researches focus on the direct utilisation of untreated RCA in SCC, the hitherto unavailable results to the properties of SCCs containing treated RCAs are presented in this paper. Four alternative aggregate surface treatment methods introduced to RCAs are two-stage mixing approach, pre-soaking in HCl solution, water glass dispersion and cement–silica fume slurry. 100% coarse RCA replacement with the natural aggregate was used in SCC mixes having constant cement dosage, fly ash replacement and water-to-binder ratio. The slump flow and T_{500} time, V-funnel time, L-box height ratio, viscosity, compressive and splitting tensile strength, and freeze–thaw cycling tests were carried out to identify the effects of these aggregate treatment methods on the key properties of SCC. Test results reveals that self-compactibility characteristics of the concretes are remarkably affected by surface treatment of RCAs. Moreover, the treatment methods of two stage mixing approach and water glass provide more dense and connected microstructures in SEM analysis leading to significant strength improvements compared to the control SCC.

1. Introduction

Due to the changes in the requirements and planning of concrete structures, excessive amount of construction and demolition (C&D) waste is generated in urban areas worldwide. Annually, 900 million tonnes of C&D waste is estimated in Europe, USA and Japan [1]. The control and management on C&D waste is becoming a worldwide challenge, especially for the major urban centres. Considering the environmental pollution and the consumption of limited natural sources it is crucial to reuse and recycle C&D waste. The production of recycle concrete aggregate (RCA) from C&D waste is important issue since it provides an alternative mean to the dependence of construction industry on natural aggregates and the critical shortage problem of natural aggregate sources. This is a common practice for several European countries, USA, Australia, and Japan. For instance, according to 2010 annual reviews, Germany, UK, Netherland, France, and USA produce recycled aggregates approximately 60 Mt, 49 Mt, 20 Mt, 17 Mt, and 140 Mt, respectively [2,3].

RCA is produced by crushing the demolished concrete waste into smaller particles generally using two-stage crushing process.

* Corresponding author. Tel.: +90 342 3172410; fax: +90 342 3601107.
E-mail address: guneyisi@gantep.edu.tr (E. Güneyisi).

http://dx.doi.org/10.1016/j.conbuildmat.2014.04.090
0950-0618/

The targeted aggregate size from the utilised crushing process influences the quality of RCA [4–8]. The properties of RCA mainly differ from its natural counterpart by the remaining hardened cement mortar adhered to the original aggregate surface as shown in Fig. 1. The amount and quality of hardened old cement mortar in the aggregate directly affect the physical properties of RCA [4] because it is characterised as porous [9–13] and presents numerous microcracks [11]. Accordingly, RCA is specified as the type of aggregate having lower density, higher water absorption, and lower mechanical strength than the natural aggregates [9,14–17]. In the case of using RCA in new concrete production, it is generally expected that these characteristics of RCA cause the adverse effect on the interfacial bond between RCA and new cement paste. Subsequently, this may result a reduction in durability, strength and workability of concrete produced with RCA [18]. Generally, the water absorption capacity of RCA affects the workability of new concrete. Additionally, the shape and texture of aggregate depending mainly on the crusher type also affect the workability of concrete [19]. RCA tends to have more water absorption capacity compared to the natural aggregate because of the presence of old cement mortar's porous microstructure [9,11,18,20–22].

The quality of interfacial transition zone (ITZ) between RCA and new cement mortar that is the connection between these two main components of new concrete poses considerable importance since it governs the mechanical strength properties of concrete [11,23]. Unlike the conventional concrete, new concrete produced with RCA has two ITZs which are new ITZ that is between RCA and new cement mortar and old ITZ that is between RCA and old adherent cement mortar. Accordingly, the structure of concrete produced with RCA demonstrates more complex material behaviour compared to the conventional concrete. Old cement mortar remaining in ITZ composes of microcracks and voids. This microstructure significantly affects the strength of concrete, leads to increase the water consumption and reduces the water required for hydration in ITZ [11]. Since RCA exhibits high water absorption capacity characteristics owing to the old cement mortar's porous microstructure, RCA in new concrete leads to reduce the effective water content for the hydration process because the adhered mortar in the old ITZ tends to absorb a large amount of water during the initial mixing stage and subsequently creates loose ITZ in the hardened concrete [24,25]. Because of this adverse effect, the high percentage replacement of RCA with natural aggregate reduces the compressive strength of conventional concrete significantly [26–28]. These drawbacks which are mainly caused by the weak and porous ITZ of old cement mortar adhered on RCA impose limitation on the widespread commercial use of RCA in structural concrete, especially in the production of self-compacting concrete (SCC).

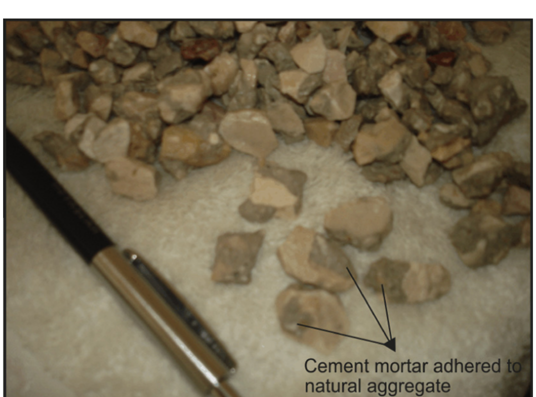

Fig. 1. Coarse RCA.

One of the promising methods to resolve the adverse effect of RCA to promote and encourage its maximum utilisation in the SCC production is to employ an effective aggregate treatment method. Hence, various techniques tend to enhance the physical properties of RCA by mainly attempting to remove the loose particles of old mortars have been investigated previously for conventional concrete production. The treatments are basically applied on RCA to attain the quality and improve the interfacial bond between RCA and new cement mortar compared to that of natural aggregate. Some of these methods improving the performance of conventional concrete (i.e. ultrasonic bath, thermal and heating methods) require the complicated mechanical equipments and utilises high energy consumption. The other potential treatment techniques that can be applied on RCA are two-stage mixing approach, pre-soaking in HCl solution, water glass dispersion, and cement–silica fume slurry. Unlike the complicated pre-treatment methods mentioned above, these techniques seemingly have potential because they are economical, effective and feasible. However, it is worthy to note that among these techniques two-stage mixing from industrial scale point of view appears to be more practical. In the current literature, to the best of the authors' knowledge, none of these treatment methods is applied to RCA used in SCC and it has not been reported how these treatment methods affect the fresh and hardened properties of the SCC. The use of RCA in the SCC is a relatively new research area on which a very limited scientific research has been carried out [29–33]. This paper presents the hitherto unavailable results to some properties of the SCCs produced with treated RCAs. It investigates the potential use of high amount of RCA in the SCC production by employing the treatments on RCA. This paper also tends to overcome this short-coming in the current literature by assessing the influenced properties of treated RCA affecting the fresh and hardened states of the SCC at 100% replacement level for the coarse aggregates.

2. Experimental details and methodology

2.1. Materials

In this study, the materials used are Type I ordinary Portland cement (OPC), fly ash (FA), fine aggregate, coarse RCA and superplasticizer. OPC (named as CEM I 42.5N) used in this study complies with TS EN 197-1 [34] (Turkish standard which is mainly based on EN 197-1 [35]). FA utilised in this research as cementitious material obtained from Yumurtalik-Sugozu thermal power plant is F type class according to ASTM C 618 [36]. The typical chemical compositions and some physical properties of OPC and FA are tabulated in Table 1. Commercially available polycarboxylic-ether type superplasticizer (SP) having specific gravity of 1.07 is used in this research.

Natural river and crushed sands were utilised as fine aggregates with maximum size of 4 mm. The values of specific gravity and water absorption are 2.66% and 0.55% for the natural river sand and are 2.45% and 0.92% for the crushed sand, respectively. Particle size gradations and some physical properties of these aggregates are given in Table 2 and Fig. 2.

RCA was used as coarse aggregate with two fractions that are in the range of 4–8 mm and 8–16 mm in order to have more control over the aggregate combination to obtain the required gradation according with TS 802 [37]. The individual gradation curves of aggregates and the combined aggregate mixture obtained using the certain proportions of fine and coarse aggregates are shown in Fig. 2.

2.2. The production of RCA

The commercial crusher system which is generally included jaw, impact and cone types of crushers in the production of RCA directly affects the shape and texture of aggregates. Jaw crusher generally produces folieceous aggregate forms, whereas the cone and impact crushers generally provide cubical aggregate forms [38]. Some researchers in the literature demonstrate the advantages of using the two-stage crushing system to produce recycled aggregates [18,39–43]. They compare the properties such as water absorption, Los-Angeles abrasion, density and crushing values of RCA obtained from the jaw crusher with the integrated systems of jaw and impact crushers. It was concluded that the two-stage crushing system was more favourable and the characteristic properties were improved by this method [18].