Construction and Building Materials 116 (2016) 151–158

Contents lists available at ScienceDirect

Construction and Building Materials

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

Influence of the artificial lightweight aggregate on fresh properties and compressive strength of the self-compacting mortars

Erhan Güneyisi, Mehmet Gesoglu, Hussein Ghanim, Süleyman İpek *, Ihsan Taha

Department of Civil Engineering, Gaziantep University, 27310 Gaziantep, Turkey

HIGHLIGHTS

- Artificial lightweight aggregate (ALWA) was produced by cold-bonding pelletization.
- Self-compacting mortars were produced with different ALWA content.
- Initial and final setting times of mortars were experimentally investigated.
- Compressive strength development of the mortars was conducted at different ages.
- ALWA significantly influenced the properties of the mortars.

ARTICLE INFO

Article history:
Received 21 December 2015
Received in revised form 7 April 2016
Accepted 26 April 2016
Available online 4 May 2016

Keywords:
Cold bonding pelletization
Fly ash
Fresh properties
Self-compacting mortar
Setting time

ABSTRACT

The current study experimentally investigated the effect of the artificial lightweight aggregate and the water-to-binder ratio on the initial and final setting times of self-compacting mortars. The artificial lightweight aggregates used in this study were manufactured through cold bonding pelletization of 90% of class-F fly ash and 10% of Portland cement in a tilted pan with an ambient temperature and moisture content. The self-compacting mortars were designed at four binder contents of 540 kg/m^3, 520 kg/m^3, 500 kg/m^3, and 480 kg/m^3 at four different water-to-binder ratios of 0.33, 0.37, 0.40, and 0.44, respectively. In each water-to-binder ratio, the natural aggregate was substituted with the artificial lightweight aggregate at the replacement levels of 0%, 20%, 40%, and 60%. Totally 16 self-compacting mortar mixtures were designed and produced. Slump flow diameter, V-funnel flow time and initial and final setting times were experimentally investigated as fresh properties while the compressive strength of the mortar mixtures were measured at 5 different ages of 3-day, 7-day, 28-day, 56-day, and 90-day. Test results showed that both initial and final setting times of the self-compacting mortars were significantly affected by the water-to-binder ratio. Addition to setting times, the slump flow diameter and V-funnel flow time was influenced by both the water-to-binder ratio and the artificial lightweight aggregate content. Moreover, the compressive strength results indicated that increasing the artificial lightweight aggregate content systematically decreased the compressive strength of the mortar mixtures at aforementioned testing ages whereas decreasing the water-to-binder ratio increased the compressive strength.

1. Introduction

High workable and as durable as possible versatile concrete demands are significantly rising especially for infrastructural needs. Hence, the development of self-compacting concrete meets these requirements and has proven its importance ever since its inception. In effect, the insufficient durable concrete structures were the main reason for the emergence of this type of concrete due to the strong correlation between durable concrete and sufficient compaction by skilled workers. Thus, the employment of the self-compacting concrete is deemed as the best solution to achieve durable concrete structures irrespective of the quality of construction work [1]. So that, this concrete is characterized by high resistance to segregation and deformability that can be cast with less energy, effort and cost consumption, that in turn accidentally serves the economic and environmental aspects [2].

The attention towards the environmental impact of construction and sustainable development has dramatically increased; also the aggregate has much to offer on this regard because it occupies about 60–70% of concrete matrix [3]. So, it is accepted as an effective way to make use of waste materials as artificial aggregates in

* Corresponding author.
E-mail address: sipek@gantep.edu.tr (S. İpek).

http://dx.doi.org/10.1016/j.conbuildmat.2016.04.140
0950-0618/

concrete or mortars. Nowadays, "green" or "environmental friendly", less expensive and satisfactory properties aggregates, are generally desirable for use in concrete, precisely in SCC [2,4]. In effect, it will contribute not only to find a solution for the waste materials disposal (by-products materials), but also to reduce the demand for natural sources; which in turn reduces the harvesting and processing of virgin aggregates. Compared with natural aggregates, the aggregate produced via using waste materials is lighter in weight and has more cellular microstructure. Thereby, the lightness of artificial aggregates reflects on the density of the produced concrete, which is usually named as "lightweight concretes" [5]. In Turkey, more than 15 million tons of fly ash is generated and produced as a by-product of coal burning [6]. Using such waste materials in a useful area can be considered as an effective way to reduce the emissions of greenhouse gases, and thereby, increase the prospects of the sustainable development [7]. In general, artificial aggregates are manufactured via either cold bonding or sintering procedures [3,8–13]. In the first process, fly ash grains conglomerate into spherical shape pellets with cement and/or lime at room temperature by using water acting as a coagulant [3,8,9,11]. This procedure is considered as more economic and preserving the environment compared to the other one, due to minimizing the consumption of energy [3,8–11]. However, it is difficult to predict the properties of produced aggregates due to the fact that several factors effect on each other during the pelletization process. So that, the mechanical factors such as speed and angle of disc or drum used to produce artificial aggregates may influence on the density, strength and water absorption ability [9,14]. Likewise, the moisture content and the grain size distribution of the raw material control the size growth of aggregates. It was reported that coarser FA grains exhibited a lower pelletization tendency as compared to smaller size [15].

Aggregate, as a main volumetric component of concrete and mortar, widely affects the properties of concrete as well as mortar, particularly for lightweight concretes. Hence, the amount and the properties of the lightweight aggregate will indicate the quality of produced concrete [10,16]. Therefore, it is crucial to identify the properties of the concrete produced by lightweight aggregate to ensure that it is appropriate for in-situ works and specification requirements. Over the last few years, several researchers had produced SCCs using this aggregate as a partial and full replacement of natural aggregate, and then investigated the properties of self-compacting lightweight concretes. The mortar of such type of concretes may directly affect the properties of such concretes. For this reason, the self-compactibility of mortar may make easier the design of self-compacting concrete [17,18]. Besides, the fresh properties of the self-compacting concrete are directly influenced by the properties of the mortar. Well-designed self-compacting mortar that satisfies the requirements for self-compactibility may be used as basis in the design of self-compacting concrete.

Videla and Martinez [19] examined the feasibility of producing lightweight concretes using fly ash lightweight aggregates through the cold bonding pelletization technique. Also, Güneyisi et al. [20] revealed the hardened characteristics of the self-compacting concretes made with cold bond fly ash lightweight aggregates. In the same regard, Gesoğlu et al. [21] investigated the mechanical properties of the concretes containing lightweight aggregate. Similarly, Baykal and Doven [9] studied the engineering performance of the moist cured fly ash pellets and the mechanical properties of its concrete. In effect, there were another literatures emphasized on the fresh properties of self-compacting lightweight concretes. In the study of Kim et al. [22], the characteristics of self-compacting concrete produced via two types of lightweight coarse aggregates were determined. Wu et al. [23] studied the workability of two types of fresh self-compacting lightweight concretes and presented mix proportion design for this concrete. As revealed in the study of Choi et al. [24], the fresh as well as mechanical properties of high-strength self-compacting lightweight concretes were investigated. Moreover, the fresh properties of self-compacting lightweight concretes containing expanded polystyrene were studied by Madandoust et al. [25]. Mortars, close as possible to concrete, were also investigated in previous studies. Güneyisi and Gesoğlu [26] discussed the properties of self-compacting mortars with binary and ternary cementitious blends of fly ash and metakaolin. Also, Safi et al. [27] replaced the fine aggregate (by sand substitution) of self-compacting mortars by seashells. Ahmadi [28] measured the initial and final setting time of conventional mortars in hot weather. Moreover, Güneyisi et al. [29] utilized two types of fly ash lightweight aggregates, one produced by cold-bonding process and the other produced by sintered method, in the production of concrete. Their results indicated that aggregate obtained by sintering method had crushing strength more than that of produced by cold bonded process. For this reason, mechanical properties, especially compressive strength, of concrete manufactured by sintered lightweight aggregate were better than concrete produced with cold bonded lightweight aggregate. Although the characteristics of self-compacting concretes including lightweight aggregate have been investigated by many researchers, the studies deal with the properties of self-compacting mortars manufactured with lightweight aggregate is limited. Westerhom et al. [30] studied on the workability and rheological properties of mortars and they revealed that crushed fine aggregate had a significant effect on workability and rheological properties of mortars especially on water demand. Moreover, their results clearly indicated that plastic viscosity of the mortar was directly influenced by the particle shape of aggregate. It was proven that mortar manufactured with angular shaped aggregate had lower workability than that was produced with spherical shaped aggregate at the same water content or cement paste volume [31,32]. Güneyisi et al. [33] studied on the self-compacting mortars produced with partially lightweight fly ash aggregate. Their results indicated that utilization artificial lightweight fly ash aggregate decreased the demand for superplasticizer.

However, the effect of artificial aggregates on the initial and final setting time of self-compacting mortars has not been addressed yet. Setting is generally employed to explain the microstructural changes that take place during the hydration of cement. Moreover, it is deemed as an essential standard consistency, beside the strength and soundness of cement and mortar. It is essential that cement or mortar set neither too rapidly nor too slowly. In the first case there may be insufficient time to transport and place the concrete before it becomes too rigid. While, too long setting period tends to slow up the work unduly, also it may postpone the actual use of the structure because of inadequate strength at the desired age. Hence, the setting time property has a great importance, particularly for in-situ works. Initial set defines the time limit for handling and placing, while the final set indicates the start of strength gaining [28]. Therefore, the test of setting does not correspond to any specific change in concrete properties but it may represent the approximate time at which the hardening begins, in case of final set. Hence, initial differs from final set whence the fresh concrete will lose its slump prior to initial set, while it will gain measurable strength sometimes after final set. Indeed, from a microstructure point of view, the better understanding of the performance of concrete or mortar will highlight the other essential properties such as durability and/or mechanical aspects. Hence, the main objective of this paper is to realize the fresh aspects of self-compacting mortars, setting time cited as an example, produced using different percentage of artificial lightweight aggregates. Moreover, the strength of mortars will be investigated in terms of compressive strength development. For this, sixteen mortar mixtures were designed using 0%, 20%, 40%, 60%