Construction and Building Materials 75 (2015) 136–143

Contents lists available at ScienceDirect

Construction and Building Materials

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

New methods development for evaluation rheological properties of self-consolidating mortars

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HIGHLIGHTS

- To evaluate the fresh properties of SCMO, three new apparatus have been suggested.
- The relations between rheological properties of SCMO are considered.
- The effect of NS and SF on the rheological properties of SCMOs is studied.

ARTICLE INFO

Article history:
Received 22 April 2014
Received in revised form 17 September 2014
Accepted 25 September 2014

Keywords:
Self consolidating mortars
Colloidal nano silica
Rheological properties
Mini column segregation
Mini J-ring
Mini Orimet

ABSTRACT

The superior performance of Self-Consolidating Concrete (SCC) and Self-Consolidating Mortars (SCMOs) over conventional concrete is generally related to their ingredients. Compared with normal mortar mixtures, the segregation resistance of self-consolidating mortar are more sensitive to small variations of properties such as gradation and moisture content of aggregates, type and dosage of superplasticizer. To study flowability and segregation of SCMOs, it is critical to be able to quickly quantify rheological properties of SCMOs. In this study, to evaluate the fresh properties of self-consolidating mortars, three apparatus (mini column segregation, mini J-ring and mini Orimet tests) have been developed as a simple and fast methods for testing rheological properties of SCMOs. In addition, the limitations of mentioned methods are proposed. The test results were in agreement with the Column Segregation test (ASTM C1610-10), the J-ring test (ASTM C 1621-09), and Orimet test (EFNARC SCC-02). Furthermore, thirty mortar mixtures containing zero to 6 percent nano silica and silica fume are prepared to verify the test methods. The results show that the mixtures containing nano silica and silica fume have higher viscosity than the control mixture.

1. Introduction

Concrete is one of the most widely used infrastructure materials in the world and usage of concrete continues to grow in construction projects [1–7]. Self Consolidating Concrete (SCC) is a new concrete that was developed in Japan in the 1980s. The goal of SCC development was to create a new concrete capable of flowing freely through concrete forms with congested reinforcement. Seismically active regions require large amounts of reinforcement, and effectively vibrating conventional concretes into such forms is really difficult. SCCs solve this problem by freely flowing into forms and around reinforcement without needing any vibration [8–10].

Because of the vast different properties of SCC from traditional concrete, other standards must be adopted to ensure quality and consistency of SCC. This concrete must be capable of moving through reinforcing steel without segregation. In addition, it must show no signs of segregation as it passes through concrete forms and also be non-viscous enough to eliminate the need for vibration and manual compaction in precast elements [11–13]. RILEM and EFNARC summarize these needs with three main requirements: filling ability, passing ability, and resistance to segregation [14–17]. Quality assurance tests that are easily performed in the field are necessary to ensure quality and consistency.

On the other way, through the absence of coarse aggregates, Self Consolidating Mortar (SCMO) has been developed in the construction over the past few decades [18,19]. In addition, the use of chemical and mineral admixtures has been critical in this development, as they can manipulate the rheological properties of SCMOs [20,21]. Therefore, it is much desired to be able to measure

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http://dx.doi.org/10.1016/j.conbuildmat.2014.09.094
0950-0618/

segregation quickly and accurately. However, there are a few papers and standards in this area. Mehdipour et al. [22] show that there exists a threshold value of fluid capacity of SCMOs and by increasing the fluidity higher than the threshold value, the risk of instability of SCMOs increases.

Senff et al. [23] continued the investigation on the effect of nano silica and silica fume on rheological properties of mortars. They concluded that mortar having more nano silica contents exhibited faster structures formation during rheology test which influenced the yield stress. In another study [24], they show that mortars exhibited noticeable differences in the rheological behavior, but less evident in temperature of hydration and compressive strength. The results of kinetics of hydration followed the same tendency found by rheology, in which samples with higher amounts of nano silica showed remarkable changes in relation to the samples without nano additives.

The objective of this paper is to evaluate the fresh properties of self-consolidating mortars. For this purpose, three apparatus, (mini column segregation, mini J-ring and mini Orimet tests) are introduced as simple and fast methods for testing rheological parameters of SCMOs. Moreover, this study attempts to investigate the relationship between fluidity and stability of SCMOs. In addition, the effects of water to binder ratio and effect of nano silica and silica fume on rheological properties of self-consolidating mortars have been investigated.

2. Experimental program

2.1. Fresh mortar tests

2.1.1. Mini slump flow (spread measurement)

ASTM® describes the slump flow test is used for monitoring the consistency of fresh SCC and its unconfined flow potential [25]. According to EFNARC [14] the apparatus for the mini slump test of SCMO consists of a frustum of cone, 60 mm high with a diameter of 70 mm at the top and 100 mm at the base. The cone was placed at the center of a steel base plate, and was filled with mortar. Then the cone was lifted immediately and the mortar spreads over the table. The average diameter of the fresh SCMOs in two perpendicular directions is measured as the mini slump flow of SCMOs as shown in Fig. 1.

2.1.2. Mini V-funnel

The most commonly used method to evaluate viscosity of SCMOs is mini
V-funnel test that measures the flow time of SCMOs through the nozzle. At this test, the funnel is filled with mortar, afterward the gate is opened. Simultaneously stopwatch starts and flow time is recorded. The instrument used in this test according to EFNARC [14] is shown in Fig. 2.

2.1.3. Mini column segregation

Segregation resistance of SCCs is commonly measured by column segregation test. However, there is not any specific standard for SCMOs, in this paper based on Mehdipour et al. [22] and Libre et al. [26] studies, an smaller and similar apparatus to the one described in ASTM C1610 [27] was used. It consists of a 75 mm diameter, 210 mm tall PVC pipe split into three 70 mm tall sections (Fig. 3). In the mini column segregation method, the contents of the top and bottom section of column are washed on No. 50 sieves after 15 min of casting. The remaining material on the sieve is dried in an oven and weighed. The static Segregation Index (SI) is given by the following formula in percent:

$$SI = 2\left[\frac{(CA_B - CA_T)}{(CA_B + CA_T)}\right] \times 100 \quad (1)$$

where CA_B = mass of aggregate retained on No. 50 sieve from bottom pipe section. CA_T = mass of aggregate retained on No. 50 sieve from top pipe section.

The acceptable segregation index for fresh concrete in most applications obtained from standard column segregation test is $SI \leqslant 15$ [27]. However, there is not any recommended limit for mortar mixtures. According to previous works [22,26], mortar mixtures with $SI \leqslant 30$ that obtained from mini-column segregation test show satisfactory stability conditions.

2.1.4. Mini J-ring

According to ASTM C 1621 [28], the purpose of J-ring test is determining the passing ability of fresh self consolidating concrete mixtures. Difference between the mini slump flow and the mini J-ring flow indicates the extent of the passing ability of a particular mixture. Although, there is not any standard for mortar mixtures, in our experimental study, two mini J-ring apparatuses were made using 8-mm deformed reinforcing bars. According to Brameshuber and Uebachs [29] the minimum recommended bar spacing for mini J-ring is 2.5–3 times higher than the maximum size of coarse aggregate. Therefore spacing of the bars was 16.7 and 14.9 mm (3 times the maximum size of aggregates). The details of the mini J-ring are shown in Fig. 4.

In this test, the mini slump cone was placed at the center of the mini J-ring and filled with mortar in one layer without any consolidation. Then the mini slump cone was raised vertically and the mortar was allowed to deform. The diameter of the mortar spread through the mini J-ring was measured in a similar way of mini

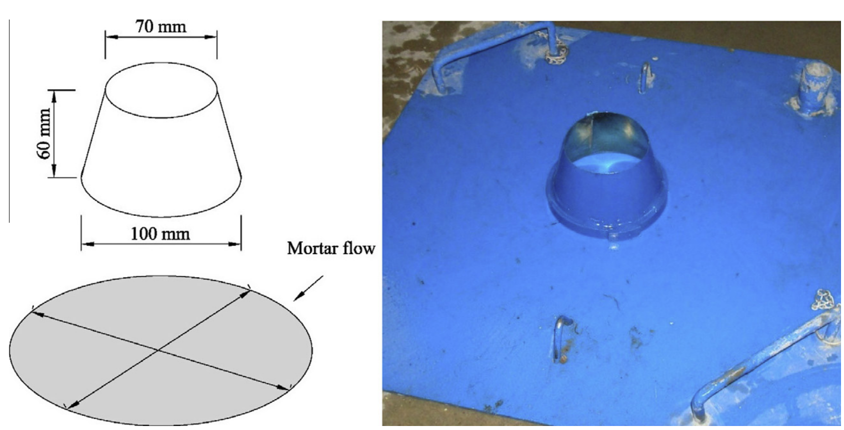

Fig. 1. Configuration of mini-slump cone.