Construction and Building Materials 158 (2018) 173–180

Contents lists available at ScienceDirect

Construction and Building Materials

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

An investigation on the fresh and hardened properties of self-compacting concrete incorporating magnetic water with various pozzolanic materials

Majid Gholhaki [a,*], Ali kheyroddin [a], Mohammad Hajforoush [a], Mostafa Kazemi [b]

[a] Department of Civil Engineering, Semnan University, 35131-19111 Semnan, Iran
[b] Department of Civil Engineering, University of Guilan, Rasht, Iran

HIGHLIGHTS

- Magnetic water treatment with SF, MK, RHA and FA was found to be suitable for improving flowability.
- SCC incorporating pozzolanic materials except FA could attain higher viscosity in V-funnel and T_{50} tests.
- SF, MK and FA except RHA caused an increase in compressive and tensile strengths of SCC mixes.
- SCC containing 20% of SF can be considered as an optimum mix design at the age of 28 days.
- Absorption characteristics of SCC improve by the inclusion of pozzolanic materials.

ARTICLE INFO

Article history:
Received 1 June 2017
Received in revised form 13 September 2017
Accepted 21 September 2017

Keywords:
Self-compacting concrete
Magnetic water
Pozzolanic materials
Fresh and hardened properties

ABSTRACT

The main objective of this study was to assess engineering properties of self-compacting concrete (SCC) incorporating magnetic water and silica fume, metakaolin, rice husk ash and fly ash (10% and 20% by weight of cement). The fresh properties were investigated by means of slump flow, T_{50}, V-funnel, L-box and visual stability index (VSI). At hardened state, compressive strength was evaluated at the ages of 7 and 28 days and mixes were cast to assess the 28-day splitting tensile strength development and also durability characteristics of concrete were tested for water absorption test at the age of 28 days. Results indicate that magnetic water and pozzolanic materials in SCC can improve the self-compatibility criteria in terms of flowability and viscosity. Furthermore, SCC mixture containing magnetic water and 20% of silica fume can be considered as an optimum mix design at the age of 28 days where compressive strength and splitting tensile strength increased up to 49% and 41%, respectively and the value of water absorption decreased up to 55%. Moreover, magnetic water can reduce the amount of high range water reducer (HRWR), required for SCC, up to 45%.

1. Introduction

Self-compacting concrete (SCC) is a highly fluid concrete which can be replaced easily in complex stirrup and rebar configuration by means of its own weight. This manner can help filling into every corner of a formwork without needing vibrator. In addition, although it is associated with higher cost due to using higher chemical admixtures, it can lead to durability enhancement of structure and reduced time for pouring concrete. SCC was first proposed by Okomorain in 1986 and the prototype of SCC was subsequently developed in 1988 at the University of Tokyo [1]. Later on, to achieve higher durable concrete, SCC has been commonly used throughout the world.

The quality of water, used into the mixer, marks a big impression on engineering properties of concrete. Also, water after passing through a magnetic field of certain strength which is called magnetic water can contribute to repulsion of cement particles from each other that causes to produce hydration layers surrounding these particles [2]. Following that, this procedure is the leading cause of avoiding accumulation of cement particles and improving flowability of concrete, the reason of which is that water can easily pass through these particles. One of the advantages of concrete mixed with magnetic water is that it requires 5% less cement compared to concrete samples incorporating tap water, and also it can

* Corresponding author.
E-mail address: mgholhaki@semnan.ac.ir (M. Gholhaki).

https://doi.org/10.1016/j.conbuildmat.2017.09.135
0950-0618/

somewhat prevent concrete from freezing [3,4]. A study by Afshin et al. [5] surveyed mechanical properties of high strength concrete by magnetic water technology. They revealed that compressive strength and slump increased by 18% and 45%, respectively.

Pozzolanic materials play a key role in producing higher durable and performance concrete and have a good compatibility with environmental protection [6,7]. Some pozzolanic materials such as fly ash (FA), limestone powder, ground blast-furnace slag and silica fume (SF) efficiently enhanced strength properties of SCC [8,9]. Furthermore, Jalal et al. [10] observed that SCC, prepared by SF, increased electrical resistivity, while it led to a decrease in absorbed water in the concrete sample and penetrating chloride ion into longer depth. They also revealed that addition of micro and nanosilica materials improved the consistency of the high performance SCC and reduced the probability of bleeding and segregation where nanoparticles in SCC mixes enhanced compressive and splitting tensile strengths. Meanwhile, they reported that addition of micro and nanosilica materials could contribute to improvement of mechanical, durability and microstructural properties of high performance SCC mixes. Also, the reduction of absorbed water from 4.5% to 2.76% and 2.57% were observed by Sabet et al. [11] for SCC mixes containing 10% and 20% SF, respectively, where they showed that replacing 10% and 20% of cement by SF resulted in an increase in the compressive strength, at the age of 28 days, to 75.5 and 79.5 MPa. They also reported that incorporation of SF increased the high range water reducer (HRWR) demand for 0.6 and 1.1 (% binder) for the SCC mixes. Generally, in another study, Jalal et al. [12] mentioned that the addition of SF improved the pore structure of concrete and it could act as a filler to enhance the density of concrete, which led to the porosity of concrete reduced remarkably. Experimental results of Leung et al. [13] indicated that when FA alone was added in SCC mixes, the reduction in water absorption was lower than using both FA and SF. This demonstrated that the effect of SF was much higher than that of FA. Furthermore, they concluded that when only FA was used to partially replace ordinary portland cement, the reduction in sorptivity was remarkable when the amount of FA was more than 20% replacement of ordinary portland cement. The results, obtained by Jalal et al. [14], demonstrated that FA in SCC could improve flowability of concrete and also SCC containing FA had the similar trend in terms of absorbed water and penetrating chloride ion into longer depth as SF did mentioned previously. They also reported that FA addition could lead to general enhancement of compressive strength of SCC mixes at the age of 90 days, while it did not affect the results of splitting tensile strength of SCC. Zhao et al. [15] in an experimental study on SCC incorporating FA and ground granulated blast-furnace slag showed that with the inclusion of FA, ground granulated blast-furnace slag enhanced the initial slump flow and reduced the slump flow loss rate, wet density of the SCC and prolonged the setting times of cement paste. By increasing the replacement level of FA, ground granulated blast-furnace slag led to a higher blocking ratio and segregation ratio of the SCC, which they remained in target range value for each test. Utilizing FA, ground granulated blast-furnace slag in the SCC had not obvious negatively affect the flowability and stability of the fresh SCC. According to the results obtained by Poon et al. [16], although concrete prepared by inclusion of metakaolin (MK) had the same strength of concrete containing SF at the age of 28 days, pozzolanic properties of MK led to higher strength of concrete at early ages and filling pores of cement paste better in comparison to other fillers such as SF and FA. As surveyed by Hassan et al. [17], replacing cement by MK raised plastic viscosity of SCC mixes, while there were no changes in SCC incorporating SF in terms of plastic viscosity. They reported that replacing 25% of cement by MK resulted in an increase in the amount of HRWR by about 30%. However, the incorporation of MK caused less need for HRWR compared to the addition of SF at the same level of cement replacement. They also concluded that with the inclusion of 8% MK, SCC could be successfully produced with higher compressive strength by about 14%. However, raising the amount of MK from 8% to 25% only improved the compressive strength up to 7%. In addition, incorporation of MK in SCC mixes could lead to higher freezing resistance and lower penetration of chloride ion into longer depth. As indicated by Dadsetan and Bai [18], MK in SCC mixes led to higher amount of C-S-H gel in presence of higher water/binder (W/B) ratio without affecting the mechanical properties. Furthermore, MK had a greater effect on the microstructural strength of the transition zone than ground granulated blast-furnace slag. Concerning rice husk ash (RHA), as shown by Madandoust et al. [19], albeit pozzolanic reaction of RHA was low at early ages of concrete, there existed a remarkable increase in strength of concrete after 270 days. They also reported that the differences between the uniformity of the properties of RHA concrete and the corresponding control mix indicated a strength variation across the depth of concrete beams following the general pattern of a reasonably uniform distribution from top to bottom, with the top region being of lower strength than the bottom region. The magnitude of this variation varied according to the concrete type, with least variation for RHA concrete. The results, obtained by Le and Ludwing [20], demonstrated that the addition of RHA in SCC mixes caused less need for HRWR and it decreased slightly filling and passing abilities and increased remarkably plastic viscosity and segregation resistance of SCC mixes. The incorporation of RHA also avoided from the bleeding of SCC mixes.

Apart from what mentioned previously, a limited number of studies have been conducted by researchers on the effects of magnetic water on SCC mixes containig pozzolanic materials, while magnetic water associated with pozzolanic materials contents can improve engineering properties of concrete mixes. As displayed by Singh and Naval [2] magnetic water could affect engineering properties of SCC mixes incorporating FA, SF and MK as binary and ternary cementatious material where the highest level of compressive strength was attained up to 47.8 MPa at the age of 28 days for SCC mixes incorporating 70% ordinary portland cement, 20% FA and 10% MK. Another study, performed by Su et al. [21,22], demonstrated that the use of magnetic water could improve compressive strength of concrete incorporating FA or granulated blast-furnace slag up to 10–20% over control mix and decreased bleeding of concrete. They also reported that the greatest increase in compressive strength of concrete was attained when the magnetic strength of water was of 0.8 and 1.2 Tesla. Meanwhile, Bharath et al. [23] indicated that the use of magnetized water enhanced the workability of concrete mixed with copper slag up to 50%. In addition, recent studies, conducted by Ghods [24] on the effect of magnetic water on the mechanical properties of SCC incorporating nanosilica, demonstrated that the compressive and tensile strengths of SCC mixes can be improved at early ages more. According to these studies, it seems that pozzolanic materials can affect performance of magnetic water in SCC mixes. For further investigation, this paper aims to present the results of SCC prepared by inclusion of magnetic water of 0.8 Tesla and SF, MK, RHA and FA (10% and 20% by weight of cement) with the W/B ratio of 0.37. The assessments of fresh properties have been performed by slump flow, required time of SCC to reach 500 mm length slump-flow diameter (T_{50}), V-funnel, L-box and visual stability index (VSI). At hardened state, compressive strength was evaluated at the ages of 7 and 28 days, and mixes were cast to assess the 28-day splitting tensile strength development and also durability characteristics of concrete were tested for water absorption test at the age of 28 days.