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Performance of Portland cement mixes containing silica fume and mixed with lime-water

Metwally A.A. Abd Elaty *, Mariam Farouk Ghazy

Faculty of Engineering, Structural Engineering Department, Tanta University, Egypt

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KEYWORDS

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Corrosion

Abstract This study is planned to investigate the properties of Portland cement mixtures containing silica fume and mixed with saturated lime water. The conducted Portland cement mixes included three groups; cement pastes, cement mortars and cement concrete mixes. The main parameters were; type of mixing solution (water or lime-water) as well as the percentage of Portland cement replaced by silica fume. Consistency level, times of initial and final settings, compressive strength development, existence and intensity of CH crystals with age, pozzolanic activity as well as efficiency of the investigated matrices to delay the corrosion of embedded steel bars were the investigated properties.

Test results show that using lime-water in mixing enhances consistency degree compared to the corresponding control mixes. Furthermore, it delays both initial and final setting times compared with traditional water due to the common ion effect principles. Moreover, combined use of lime-water and silica fume enhances the pozzolanic reaction that was identified by the strength development at both early and later ages. The existence of CH crystals for higher percentages of silica fume (up to 30%) for further reaction at later ages was observed by XRD results. Moreover, combined use of silica fume and lime-water ensures a high alkaline media around steel bars from the moment of ingredients mixing as long as later ages despite of pozzolanic reaction that was identified from results of chloride attack.

Introduction

Several researchers have studied the use of pozzolanic materials as a mineral addition to cement based composites to obtain construction materials of enhanced engineering properties. This is due to their influence on microstructure and durability of the blended cement composites [1–3].

The sources of the mineral admixtures are the by-products of many industries. The common types of minerals from industrial by-products are fly ash, rice husk ash, silica fume (SF) or condensed silica fume (CSF), blast furnace slag and other

* Corresponding author. Tel.: +20 1006750733.
E-mail address: drmet2828@yahoo.com (M.A.A. Abd Elaty).

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slags. The uses of these minerals result in ecological, economic and energy saving considerations [4].

As reported by many authors, supplementary cementing materials such as SF have a beneficial influence on reinforced concrete durability [5]. Laboratory tests of silica-fume concretes have shown a reduction of concrete water permeability and concrete chloride diffusion coefficients [6]. Factors such as fineness, water to cementitious materials ratio, curing temperature and alkalinity of the pore solution have been thoroughly examined in an attempt to explain the reactivity of this material and relate its pozzolanic potential with the evolution of the hydration procedure [7].

A pozzolanic material requires calcium hydroxide $Ca(OH)_2$ or (CH) in order to form strength producing products (pozzolanic activity); whereas a cementations material contains quantities of CaO and can exhibit a self-cementitious (hydraulic) activity. Usually, the CaO content in these materials is not enough to react with all quantities of the pozzolanic compounds; thus, they also exhibit pozzolanic activity (pozzolanic and cementitious materials). However, these materials are used in combination with Portland cement, which yields on its hydration, the CH essential for their activation [8].

Authors of Ref. [9] reported that SF exhibits higher pozzolanic activity than metakaolin whereas fly ash exhibits lower one compared to that of metakaolin. This is due to chemical and mineralogical compositions, pozzolanic activity, fineness ... etc.

Replacing some of the cement content in concrete mix by mineral admixtures is being the recommended aim due to pollution problems. But replacing of cement in concrete by mineral admixtures produces an immediate dilution effect [10]. However an increase in the strength of concrete was observed at later ages. This is due to the well-known chemical reaction between pozzolans and CH released from C_3S and C_2S hydration.

In essence, the liberated CH crystals are responsible for the formation of the passive layer around the reinforcement of reinforced concrete members. But when highly active pozzolan materials are used in cement based mixes, they remove CH from the system and accelerate the ordinary Portland cement hydration.

Hydrated lime was used as an admixture in poured concrete in the beginning of the 20th century [11]. This was due to the improved water tightness and impermeability. However, this use has largely disappeared due to increasing strength, finer grinding of Portland cement and the interaction of the chemical admixtures. From other points of view, the employment of pozzolan mixed with lime, of similar fineness to that of the OPC, will reduce the risk of concrete decalcification, even for large substitution volumes, starting by the pH rising of the water contained in pores, which would prevent the reinforcement passive protection [12]. Moreover, the effects of hydrated lime and SF on fly ash concrete in improving its early age strength and other properties were studied [13]. The air permeability of concrete containing lime and SF either decreased or remained almost the same when compared to the concrete without these ones. The addition of lime and SF also improved the sorptivity of concrete.

Due to the trend of using friendly environmental materials in the field of cement and concrete industries, complete utilization of cementitious and pozzolanic by-products is highly recommended [14,15]. However, the need for increased use of supplementary cementing materials in concrete requires more available CH, which was tried through using lime putty addition to concrete mixes. Lime putty addition has been already proved beneficial for durability properties [16].

Authors of Ref. [17] determined compressive strength of SF mortar having proportion 1:1:6 (cement + silica fume:lime: sand). They concluded that in Portland cement mortars, SF acts mainly at the interface paste-aggregate, where there is a higher concentration of CH and greater porosity than in paste. In Portland cement mortars with SF, lime is better suited in the paste and there is no evidence of concentration of SF at the interface of paste and aggregate.

Through the use of differential scanning calorimetry and thermo gravimetric analysis (DSC/TG), it was demonstrated that the addition of hydrated lime increased the $Ca(OH)_2$ content; whereas the addition of SF decreased the $Ca(OH)_2$ content in the cement paste. The mercury intrusion porosimetry (MIP) data confirmed the beneficial action of hydrated lime and SF, toward decreasing the total pore volume of fly ash cement paste [13].

Since the pozzolanic reaction needs CH crystals to occur and keeping in mind that a period to be waited until the release of the CH crystals as a product of cement hydration and even after the release of CH crystals they will be consumed by pozzolanic materials through the pozzolanic reaction. All of these draw our attention to the importance of early supply cement based mixes with CH at early ages. This could be achieved by using saturated lime-water LW instead of water W in mixing. Therefore, the objective of the current study is to investigate the influence of using LW in comparison with traditional mixing W on setting, hardening and corrosion properties of Portland cement based mixes modified by SF.

Research significance

Pozzolanic reaction for Portland cement based mixes requires CH crystals to take place. Release of CH crystals is based on hydration of C_2S and C_3S crystals which is a function of time. It takes a relatively short period for hydration of C_3S whereas, for C_2S it needs a relatively long period. Consequently, the pozzolanic reaction is delayed up to the release of CH crystals.

This paper introduces an idea for early supply of the Portland cement mixes containing SF with CH crystals through using LW as a solution in mixing instead of traditional W.

So, the main goals of this paper are to:

- o Study of the consistency level as well as setting properties of Portland cement based materials containing SF and mixed with LW solution.
- o Investigate the hydration process of Portland cement based materials containing SF and mixed with LW.
- o Explore the influence of using LW as a mixing solution on corrosion of steel imbedded in Portland cement base mixes containing SF.

Experimental program

An experimental program to evaluate the performance of Portland cement based materials containing SF and mixed