Cold Regions Science and Technology 87 (2013) 1–5

Contents lists available at SciVerse ScienceDirect

Cold Regions Science and Technology

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

Use of tabletting & coating accelerator for the prevention of early-frost of concrete in cold weather

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ARTICLE INFO

Article history:
Received 27 July 2012
Accepted 30 November 2012

Keywords:
Tabletting
Accelerator
Polyvinyl alcohol (PVA)
Pan-coating method
Workability
Early-frost

ABSTRACT

The use of accelerators prevents early-frost by developing strength of concrete in cold weather. However, no security of workability occurs because early hydration makes them to react rapidly. Thus, the accelerators via tabletting were coated with polyvinyl alcohol (PVA) of water-soluble polymer substance. The discussion includes the following: mortar setting time, workability by elapsed time, early strength to assure the development of adequate strength, and freezing–thawing resistance. As a result, workability can be secured as well as the development of early strength to prevent early-frost. The porosity and progress of hydration affecting the concrete were also found to be superior by analyzing the mercury intrusion porosimetry (MIP) and scanning electron microscopy (SEM) results.

1. Introduction

When concrete is placed under low temperature in cold weather, it is anticipated to have serious damage in quality due to freezing. This is called early-frost, which indicates strength degradation, spalling, and cracking due to freezing in the initial hardening stage, and repeated freezing–thawing cycle after placement of concrete in low temperature (Mehta and Monteiro, 2006; Suprenant, 1985). The basis to prevent early-frost will assure the development of adequate strength to prevent freezing of concrete in initial stage (ACI 306R, 2010). When cold-weather concrete is utilized, the methods of hot air curing mix proportion adjustment, and others are used to prevent the concrete from being damaged due to early-frost. Nowadays, the hybrid method by admixtures and hot air curing has been used. In cold-weather, the use of accelerators among admixtures has advantages, particularly in terms of preventing early frost and improving early strength. Workability, however, is hard to secure because early hydration of accelerators makes them to react rapidly (Brook et al., 1988; Hama and Kamada, 1999; Prudencio, 1998).

Therefore, the control technique of the accelerator's reaction time in cold weather concrete will be required. Although the control accelerator's reaction time conducted tabletting method in previous research, the concrete with tablet, as part of the tablets crashed due to friction between the aggregates and the mixer blade in early mixing, reacted without securing workability. If the tablet is placed after mixing other materials, the desired performance may not occur due to poor tablet distribution (Ryou and Lee, 2012).

The coating, whose objective includes the protection of contents, exterior improvement, and control of work performance, and others, is used mainly in foods and medicines. Main coating methods in this field were pan-coating method, fluidized-bed coating method, press-coating method, and others (Dale, 1959; Loyd et al., 2005; Yang et al., 2007). The pan-coating method is most common, as shown in Fig. 1.

In this study, tablets were used as accelerators, which have the advantage of preventing early-frost and in developing early strength. The tablets were then coated with water-soluble polymer substance.

Whether the operation time can be secured by adjusting the reaction time in the early stage and whether early strength can be developed due to accelerator's function by dissolving water-soluble coating material in the following stage are evaluated by testing.

2. Experiment

The surface of the accelerators via tabletting was coated with water-soluble polymer substance, which used polyvinyl alcohol (PVA). The PVA as coating materials can withstand friction between the aggregates and the mixer blade in early mixing due to stiffness. Water-solubility can be adjusted depending on multiple grades (degree of deacetylation) (Korsmeyer et al., 1985; Peppas, 1997; Ravve, 2003).

The coating method of the tablet is pan-coating method. The blending solution of PVA and purified water was sprayed to the tablet of pan-inside, which simultaneously blew hot air. The tablet surface was then bonded with PVA by evaporation of purified water. Repeating this process can increase coating thickness (Heinämäki et al., 1997; Ruotsalainen et al., 2003). The PVA coating is 0.01–0.05 mm in thickness when the process is repeated at least twice. The features

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http://dx.doi.org/10.1016/j.coldregions.2012.11.005

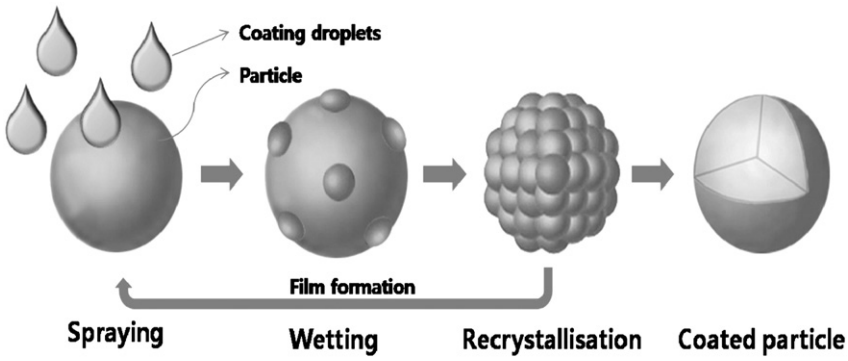

Fig. 1. Process of pan-coating method.

of tablet and coating are shown in Table 1. Fig. 2 shows PVA-coating tablet and close-up image.

The mortars for setting time were made with W/C = 0.5 and with a cement-to-sand ratio of 1:3, according to ISO 679. For the characteristics of concrete made with 10-level specimens, in the pilot test, the concrete mixtures were found to have the following properties: W/C = 52.0%, S/a = 48.5%, target slump = 150 mm, and target strength = 24 MPa. Table 2 shows the replacement ratio for each testing.

When water was added, the cement gradually lost its workability with slight heat, and then it hardened because a new matrix was developed by the cement clinker which reacted with the water. This step is called setting. The hardening after the end of the setting is a step on the development of measurable strength. In general, setting and hardening time were retarded in cold weather (Mindess et al., 2003).

In this study, the setting time was measured according to ASTM C 403. After curing in a temperature and humidity chamber, the penetration resistance was measured depending on the elapsed time. The setting time was measured according to the graph of the curved hand fitting that was drawn after points were indicated using the penetration resistance and the elapsed time (the initial and final setting times were decided at 3.5 and 28 MPa, respectively). The dissolved time of the PVA coating was then evaluated by the difference of the initial setting time depending on the coating's presence.

To determine the possibility of developing early strength and of securing workability in fresh concrete, a slump test was conducted at 60-minute elapsed time according to ASTM C 143. After curing under the typical cold weather protection of 15 °C temperature and 60% humidity in the temperature and humidity chamber, the compressive strength was checked after 24 h to see if it matched the minimum compressive strength of 5 MPa for early-frost prevention according to ASTM C 39 (KCI, 2009).

Although for the early-frost prevention meet to compressive strength, severe repeated freezing and thawing may cause frost damage (Cai and Liu, 1998). Accordingly, procedure B of the standard test method described in ASTM C 666 was conducted, and the long-term frost resistance was evaluated based on the relative dynamic elastic modulus. The test is continued (either continuously or intermittently) for 300 cycles or until the relative dynamic elastic modulus has reached 60% of its initial value, whichever occurs first.

Sampling was conducted after the hydration progress was stopped by acetone on 24-hour specimens, which developed early strength. The presence of harmful pores after PVA coating tablet reaction and the presence of the hydrates affecting early strength were evaluated by analyzing the MIP and SEM results. In particular, it has advantage that the porosity and pore-size distribution can be easily determined through mercury intrusion porosimetry (MIP) test (Kumar and Bhattacharjee, 2004).

Table 1
Features of the tablet and the coating.

	Features
Tablet	Shape: cylindrical, diameter: 5 mm, length: 5 mm Main ingredient: aluminate-based accelerator (Acc.) Tabletting method: direct compress
Coating	Polyvinyl alcohol (PVA)to water ratio = 1:12 Coating thickness: 0.01–0.05 mm Coating method: Pan-coating

3. Results and discussion

In Fig. 3, the initial setting time was shortened depending on the increased replacement ratio, as the main ingredient of the tablet is accelerators, which were directly involved in the hydration and setting

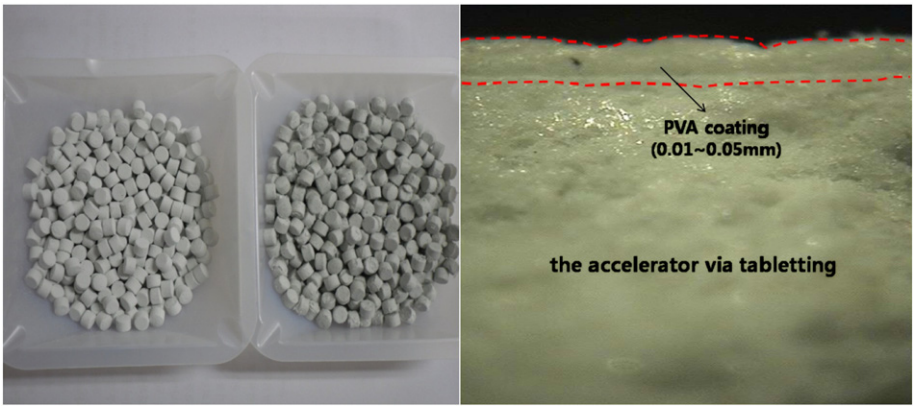

Fig. 2. PVA coating tablet and close-up image.