Construction and Building Materials 101 (2015) 410–416

Contents lists available at ScienceDirect

Construction and Building Materials

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

Effect of curing compounds on the properties and microstructure of cement concretes

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HIGHLIGHTS

- Four types of curing compound were investigated.
- Both macro and micro tests were conducted.
- Curing compound improved strength and durability of cement concretes.
- Curing compound promoted the hydration and microstructure.

ARTICLE INFO

Article history:
Received 27 May 2015
Received in revised form 24 September 2015
Accepted 18 October 2015

Keywords:
Curing compound
Cement concrete
Mechanical properties
Durability
Microstructure

ABSTRACT

With the aim of specifying the type of curing compound for water-scarce areas, four types of curing compound (acrylic-based, paraffin-based, silicate-based and composite-based) were chosen to investigate the effect of curing compound on the mechanical property, durability and microstructure of cement concretes. The effect was assessed by measuring compressive and flexural strength, drying shrinkage, impermeability and crack resistance. The results indicated that curing compounds were effective in increasing the compressive, flexural strength and the impermeability of concretes, and decreasing the drying shrinkage and cracks. In general, the composite-based and the acrylic-based curing compound performed better than the paraffin-based and the silicate-based curing compound. At the same time, microstructure test results showed that curing compound promoted the hydration of the cement to form a compact and homogenous microstructure, and AFt crystalline particles were rod-like with a larger size.

1. Introduction

Curing is an essential process for concrete to achieve its potential strength and durability [1–4]. The objective of curing is to keep concrete saturated or as nearly wet during cement hydration. The hydration of the cement will continue for years as long as the concrete contains water. Once the water is lost, the hydration of the cement will cease. Curing can be applied in two ways. One way is to wet the exposed surface of the concrete continuously with water, such as sprinkling water or vapor, or ponding water. Another way is to minimize water evaporation of the concrete, such as leaving formwork in place, covering the concrete with plastic sheets or a suitable curing compound.

Curing with water is a general and effective way, but it also has its limitations. Firstly, it is a time-consuming and water-consuming method which may be unpractical in regions with scarcity of water; secondly, it can only be preceded after the final setting time of the concrete which may lead to the early-cracking of the concrete in a hot and dry environment; besides, it may cause the foundation freeze injury in freezing area. For curing with formwork or plastic sheets, the curing efficiency may decrease drastically once the formwork or sheet is broken by human activities or nature. Moreover, it is not suitable for curing complex structures.

Recently, curing compound has received much attention due to its properties of water-saving, high-efficient quality and extensive applicability, which offers important economic benefits for the concrete maintenance engineering in water-scarce areas [5–8]. Curing compound is a kind of emulsion or solution. The former can form a moisture retentive membrane by evaporation of its volatile component when it is applied to the surface of the concrete (such as acrylic-based, paraffin-based). The latter can react with cement paste to generate calcium silicate gel as to block the surface pores of the concrete to minimize water evaporation (such

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http://dx.doi.org/10.1016/j.conbuildmat.2015.10.124
0950-0618/

as silicate-based). The composite-based curing compound has both above-mentioned functions.

Al-Gahtani [9] assessed the effect of different curing methods on plain and blended cement concretes. The results showed that the concrete specimens cured by wet burlap had higher strength development than specimens cured by water-based and acrylic-based curing compounds. Both kinds of curing compound effectively decreased the drying and plastic shrinkage of plain and blended cement concrete. What's more, acrylic-based curing compound performed better than the water-based curing compound.

Choi et al. [10] explored the ways to improve the effectiveness of curing operations. They noted that curing had substantial effects on the performance of Portland cement concrete (PCC) pavement. The quality of curing materials, the time, and amount and uniformity of application had great influences on the effectiveness of membrane-forming curing compound. Alizadeh et al. [11] tested the values of diffusion coefficient and surface chloride content under different curing conditions. Radlinski et al. [12] evaluated the effect of curing compounds on scaling resistance of ternary concrete produced with fly ash and silica fume.

According to Yilmaza and Turken [13], each curing materials presented various results for concrete specimens produced with no admixture and different chemical admixtures. For concrete specimens produced with some particular types of chemical admixture, curing materials increased the compressive strength of specimens. However, curing materials reduced the compressive strength of specimens produced with another types of chemical admixture. It is necessary to make preliminary tests in the laboratory to select the most suitable curing material for the concretes produced with different chemical admixtures.

So far in the literature, ample researches have been conducted to evaluate the effect of curing conditions on the properties of concretes. However, little research results have been reported at this point concerning the effect of curing compounds on the durability of the concrete, especially drying shrinkage, impermeability, cracking resistance. In addition, the effects of curing compound on micro-properties of concretes remain unclear. This study was conducted to evaluate the effect of four types of curing compound on the strength, drying shrinkage, impermeability, crack resistance and microstructure of cement concretes with the aim of specifying the type of curing compound for water-scarce areas.

2. Methodology

2.1. Materials

GB 175-2007 PO42.5 type cement was used to prepare the concrete mixture. Table 1 shows the chemical compositions of PO42.5 type cement. Fine and coarse aggregates complying with standard JTG E42-2005 were used. The properties of these aggregates are shown in Table 2.

The concrete mixtures were proportioned on a weight basis. The slump of concrete mixtures should be controlled within 30–50 mm. In order to control the test variables, no else cementing material and chemical admixture was used. And the following parameters were kept constant in the study.

Table 1
The chemical compositions of PO42.5 cement.

Constituent (wt.%)	PO42.5 cement
SiO_2	24.19
Al_2O_3	4.07
Fe_2O_3	3.79
CaO	59.21
MgO	2.64
Na_2O	0.17
K_2O	0.61
SO_3	2.63
IL	2.67

Table 2
The properties of fine and coarse aggregate.

Fine aggregate (river sand)	
Apparent density (g/cm^3)	2.65
Fineness modulus	2.6
Sediment percentage (%)	1.7
Coarse aggregate (crushed limestone)	
Type of gradation	Continuous grading
Crushed stone value (%)	4.2
Grain size (mm)	5–20
Flat and elongated particles (%)	5.3

(1) Cement content: 360 kg/m^3.
(2) Fine/coarse aggregate ratio: 0.61.
(3) Water cement ratio: 0.5.

The basic properties of curing compounds are shown in Table 3.

2.2. Specimen preparation

The concrete constituents were plunged into 60 L mixer at once and mixed for 3 min. The temperature of materials and environment should be remained at 20 ± 5 °C, and the relative humidity should be controlled at 50 ± 10%. Plastic molds were used and the hole of mold was sealed. The specimens of microstructure test were chosen from the surface coat of concretes.

2.3. Curing condition

The concrete specimens were cured by water or air, or one of curing compounds. The concrete specimens cured by water or air were treated as control specimens. The specimens cured by water were conserved in a standard curing room (20 ± 2 °C, RH $\geqslant$ 95%) and kept surface moist at all times. The specimens cured by air were conserved in the same environmental conditions (20 ± 2 °C, RH = 50 ± 10%) with the specimens cured by curing compounds, and only difference between these two curing methods is the use of curing compound.

The curing compounds were sprayed evenly onto the top surface of concrete specimens until the surface water of concretes disappeared. The dosage of curing compound was controlled at 200 g/cm^2. The vertical surface and the bottom surface of specimens were sprayed by curing compounds after the removal of molds.

2.4. Test techniques

3 d, 7 d and 28 d compressive and flexural strengths of concrete specimens cured by four curing compounds were tested. Besides, third point load was used for flexural strength test. 1 d, 2 d, 3 d, 7 d, 14 d, 21 d, 28 d, 56 d and 90 d drying shrinkage of concrete specimens were tested by Horizontal shrinkage tester (see Fig. 1(a)). Data was recorded in real time by dial indicator.

Impermeability of concrete specimens after curing for 3 d, 7 d and 28 d was tested. During the test, water pressure of permeability instrument was kept at 1.2 ± 0.05 MPa for 24 h. The test was end until the top surface of specimens had seepage or the test time had reached 24 h. Then the truncated cone-shaped specimens were taken out from the instrument, and split up under the press machine (see Fig. 1(b)), and permeation height of each specimen was recorded.

Crack resistance of concrete specimen was tested according to standard CCES 01-2004. At first, the concrete specimen with a size of 600 mm × 600 mm × 63 mm was poured into a cuboid mold, which has several bolts welded around it as to induce the development of cracks (see Fig. 1(c)). After curing for 8 h by each curing method, specimens were put in a dry and windy condition (20 ± 2 °C, RH = 35 ± 5% and wind velocity = 0.6 m/s), and then test began. Lastly, the numbers and areas of crack at the first 3 testing days were observe and recorded by crack observation instrument timely.

Table 3
The basic properties of curing compounds (according to standard JC 901-2002).

Properties	Acrylic-based	Paraffin-based	Silicate-based	Composite-based
Main ingredients	Acrylic	Paraffin	Silicate	Acrylic + paraffin + silicate
Effective water retention (%)	76.6	63.4	45.5	78.7
Solid content (%)	29.82	38.26	25.30	35.58
Drying time (h)	1.2	2	2.5	1.5
Water solubility	Insoluble	Insoluble	Soluble	Insoluble