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An experimental investigation of hydration mechanism of cement with silicane

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HIGHLIGHTS

- The hydration mechanism of cement paste with diverse silicane dosages were revealed.
- The connection between macroscopic and micro-mechanism of cement paste were explained.
- The XRD, FT-IR, Nitrogen-absorption test and SEM was used to evaluate the mic-mechanism.

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ABSTRACT

The article aimed mainly to research the influence of silicane on the hydration mechanism of cement paste containing different dosages silicane using Standard consistency water consumption, the setting time, fluidity, porosity and the degree of hydration test. Meanwhile, the Micro-structures mechanism of cement paste were researched by the Fourier transform-infrared spectroscopy (FT-IR), X-ray diffraction (XRD), Nitrogen-absorption and Scanning electron microscopy (SEM). Modified cement paste specimens were prepared by adding 1%, 3% and 5% silicane into control cement paste, respectively. the Standard consistency water consumption and the setting time were evaluated using Vicat apparatus. Non-evaporable water content was employed to assess the degree of hydration of the cement paste. The fluidity of cement paste specimens was characterized using flow table apparatus. Experimental results showed that for the silicane and mix designs used in the article, the incorporation of silicane generally increased the fluidity, porosity and setting time, however, decreased the degree of hydration and Standard consistency water consumption compared with the control cement paste. In addition, the analysis of XRD, FT-IR, Nitrogen-absorption test and SEM revealed the hydration mechanism and the connection between macroscopic and micro-mechanism of cement paste incorporating different dosages silicane.

1. Introduction

Along with our country city construction development, as an indispensable modern civil engineering in the largest amount, the most widely used cement play a significant role. Cementitious materials are very complex composites with entire properties which are dominated by the characteristics of different components, their interfaces and microstructure. The service of cementitious materials structures, especially civil engineering structures, depends on significantly the interactions of construction materials, loading conditions and external environment. The need for an increasing service life is increasingly important in the cementitious materials field, which lead to the attempt that improve the durability and mechanical strength of the construction cementitious materials [1]. To satisfy these requirement, the improved civil engineering construction materials and the internal treatment seem to necessary.

Adding silicane into cementitious materials have increasingly attracted considerable attentions in recent years [2-5], due to the fact hydrolysis of alkoxyl groups (-OCH_3 or -OC_2H_5) to hydroxyl groups (-OH) and a subsequent condensation with hydroxyl groups on the substrates forming siloxane covalent bonding progressively occur acidic or alkaline situation [6,7]. It made the silicane applied in very wide field, for example, as coupling agents in inorganic filler modified polymers materials [8,9], as silicane fume coating for lower shrinkage property and better workability [10,11], as polymer fiber or steel fiber in fiber reinforced mortars for enhancement of the interfacial bonding and the increment of fiber dispersion [12,13], and as water repellent agent in concrete or cement mortar to decrease water penetration [14–16].

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Previous endeavor has been tried to use silicane as a curing agent for surface protection in cementitious materials. Xu [8] introduced that adding silicane regarded as an admixture into cement can importantly enhance the basic properties of cementitious construction materials. This was clearly seen that the tensile strength, bending strength and fluidity of cement paste were improved due to the incorporation of silicane. Similar experimental results have been shown in cement mortars with silicane-treated sand and fiber reinforced mortars [12,13]. Now days, a fresh class of silicane modified polycarboxylate superplasticizer was improved and drawn considerable attentions [17,18]. It has been testified that the reaction between the silylated functions and the silicate has improved the sorption of polycarboxylate molecules on the surface of cement particles. In the recent research, Svegl et al. [19] investigated that aminosilicanes (N-2-aminoethyl-3-aminopropyltrimethoxysilicane and aminopropyltrimethoxy silicane) confirmed the durability of cement mortars and decreased the water demand.

On the other side, the specific hydration mechanism of silicane in cementitious construction materials have been rarely investigated. It has been illustrated from previous reports that the addition of various silicane might be useful in cementitious construction materials for some physic properties, such as compressive strength, bending strength, workability and impermeability. However, why different content silicanes work differently and how the silicane effect these physic properties of cementitious materials remain still unfamiliar. The target of the article is to carry out various essential experiments for better comprehending the hydration mechanism of silicane in cementitious construction materials. The effect of different dosages silicane (tetraethoxysilicane) including 1%, 3% and 5% silicane dosages on the Standard consistency water consumption, setting time, fluidity, porosity and the degree of hydration of cement paste was systematically researched in the article. Technique including X-ray diffraction (XRD), Fourier transform-infrared spectroscopy (FT-IR), Scanning electron microscopy (SEM) and Nitrogen-absorption test was adopted to supervise the cement paste hydration procedure, and to illustrate the connection between micro-structure and macro-properties of cement paste at different ages of curing.

2. Materials and experimental method

2.1. Materials

42.5 R type Normal Portland cement, complied with Chinese standard GB175-2007 and obtained from the Hubei HuaXin cement Co., Ltd, was used as a blinder for cement paste with and without silicane. Physical and chemical compositions of the cement were shown in Table 1, which were acquired based on the Chinese standard GB/T176-2008 "Chinses Analysis of Cement". Silicane coupling agent including γ-aminopropytriethoxysilicane (APTES) was employed for the preparation for silicone modified cement paste, purchased from Diamond material of Chemical Company in China. Its chemical properties were shown in Table 2, and molecular structures are shown in Fig. 1. Tap water was employed on whole experiment. The detailed hydrolytic process of APTES could be shown in Fig. 2.

Table 1
Physical and chemical properties of cement.

Chemical composition	Unit	Ordinary Portland cement
SiO_2	%	19.9
Al_2O_3	%	4.6
Fe_2O_3	%	3.0
CaO	%	64.6
MgO	%	0.78
SO_3	%	2.37
Na_2O	%	0.06
K_2O	%	0.65
Cl^-	%	0.01
Loss on ignition	%	3.11
Blaine fineness	M_2/kg	375

2.2. Preparation of specimens and paste experiments

Measurement of the Standard consistency water consumption, setting time and fluidity were implemented on fresh cement pastes, while the porosity and the non-evaporable water content were carried out on the cement paste specimens. In the preparation of fresh cement pastes, water/cement ration of 0.25 was used for preparing mixtures incorporating different silicone contents as cement paste additives, respectively. The mixture proportion with silicane were shown in Table 3 and the specific operation process of these specimens as follows: for cement paste specimens, first, the 42.5 R type Normal Portland cement was slowly put into the 2.5L stirring mixer pre-charged, then, the total tap water was added into it and stirred at 60 rpm for 60 s. Afterwards, the different silicane contents were added and stirred at 60 rpm for additional 60 s. After a halt for 10 s, the cement paste compounds

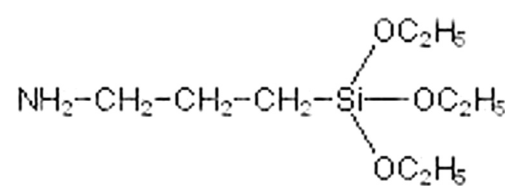

Fig. 1. Molecular structure of γ-aminopropytriethoxysilicane (APTES).

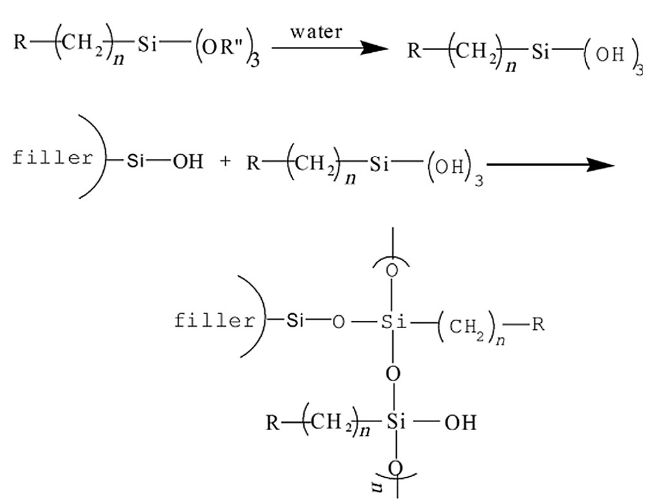

Fig. 2. hydrolytic process of APTES.

Table 2
The properties of silicane.

Molecular formula	Boiling point	Density	Purity quotient	Solubility
$NH_2CH_2CH_2CH_2Si(OC_2H_5)_3$	217 °C	0.946 g/cm3	≥97%	Dissolved in water