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Effects of carbamide on fluidity and setting time of sulphoaluminate cement and properties of planting concrete from sulphoaluminate cement

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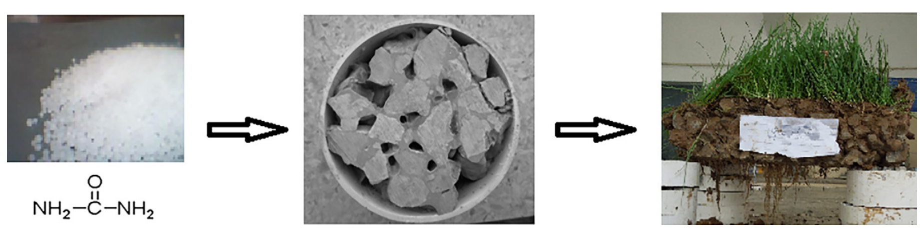
HIGHLIGHTS

- Carbamide increased setting and fluidity of SAC and was released slowly in concrete.
- With the increase of carbamide amount to 2.5 wt.% the permeability coefficient of SAC-based planting concrete caused by fluidity of paste increased to 23.2 mm/s which was 21.5% higher than that without carbamide.
- With the increase of the amount of carbamide the release amounts and cumulative release rates of nitrogen nutrients increased, which led to alkalinity and compressive strength of planting concrete decreased.

GRAPHICAL ABSTRACT



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ABSTRACT

In this paper carbamide as the fertilizer was added into planting concrete. As carbonic acid was produced during carbamide hydrolysis the fluidity and setting time of sulphoaluminate cement (SAC) was studied to investigate its effects on properties of cement. Its effects on compressive strength, water permeability coefficient, alkalinity and nitrogen release of concrete and stem length of plants were studied to evaluate the adaptability of SAC concrete for plant growth. Results revealed that carbamide extended the initial and final setting time of SAC paste and increased its fluidity because carbamide was soluble in water and carbonate ion produced from carbamide dissolution reacted with calcium ion from cement hydration. Subsequently calcium carbonate was formed which covered the surface of unhydrated cement grains so that prohibited their hydration. With the increase of carbamide amount to 2.5 wt% the permeability coefficient of SAC-based planting concrete caused by fluidity of paste increased to 23.2 mm/s which was 21.5% higher than that without carbamide. With the increase of the amount of carbamide the release amounts and cumulative release rates of nitrogen nutrient increased, leading to decreasing in both alkalinity and compressive strength of planting concrete. With the increase of curing age compressive strength of planting concrete increased and alkalinity reduced stably, which was desirable. At

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14 and 21 days after budding with the increase of carbamide content, stem lengths had a trend to increase and were obviously greater than that in concrete without carbamide, which was in good correspondence to release rate of nitrogen nutrient from planting concrete.

1. Introduction

Planting concrete, a unique and environmentally friendly material, is made of cement, water, usually single-sized coarse aggregates and little or no fine aggregates. It is usually used as plant bedding to fix and preserve soil [1–6]. But it has been found that there is lack of nutrition in planting concrete, which usually causes plants withering and even dying away. So, in this paper carbamide as fertilizer was added into planting concrete to provide nutrition for planting growth.

However, carbamide has an evidently adverse effect on Portland cement (PC) hydration. Carbonic acid, produced from carbamide dissolution in water, reacts with calcium hydroxide, which subsequently negatively affects hydration of Portland cement [7]. Carbamide crystals formed in capillaries and pores restrict the thermal humidity deformations of concrete. When pressure caused by carbamide crystals exceeds the critical value, concrete capillaries crack and the destruction of surface layers starts [8]. In this paper sulphoaluminate cement (SAC) was used as cementitious material because its pore fluid alkalinity is lower than that of PC towards the favor of plants growing [9–13], but silicate minerals in SAC still exists, so it is believed that carbamide affects hydration and performance of SAC.

Planting concrete is required to gain proper porosity to meet plants growing demand and high enough strength to protect soils. Huang et al. found that carbamide can reduce the water demand of SAC [14]. In their study, fluidity of planting cement paste increased from 80 to 149 mm with carbamide content increasing from 0.2 to 4.0 wt%, suggesting that too much slurry possibly blocked the pores of planting concrete, which inevitably affected plants growing in concrete. The porosity, especially the connective porosity, played a significant role in the functional and structural performance of porous concrete. The porosity of planting concrete was required not to be less than 25% [15,16]. Plant roots needed to go through the concrete and reach soil below it to gain nutrient and water to grow as soon as possible, which required concrete possessing adequate pores, especially interconnected pores. At the same time compressive strength can be related to the porosity and critical pore sizes [17]. Usually higher porosity leads to lower strength for concrete. The planting concrete needs a certain strength high enough to resist the scour, for instance from water. Therefore, when carbamide is added into SAC concrete, its effects on performances of SAC-based planting concrete need to be investigated.

In this study, carbamide as fertilizer was introduced into planting concrete. Its effects on fluidity and setting time of SAC, compressive strength, water permeability coefficient, alkalinity and nitrogen release of SAC-based planting concrete and stem length of plants growing in SAC-based planting concrete were studied. The findings of this research lay the foundation for preparation and application of planting concrete which is able to slowly release fertilizer for plants growing during its service life.

2. Experimental

2.1. Raw materials

2.1.1. Sulphoaluminate cement

SAC used in this paper was made in Zibo, China with their chemical and mineral compositions shown in Table 1 and Fig. 1, respectively.

2.1.2. Coarse aggregates

Coarse limestone aggregates with particle sizes of 19.0–26.5 mm were used for making SAC concrete in this study. Their bulk density was 2710 kg/m^3 and crushing index was 8.7%.

2.1.3. Admixtures

In order to improve the setting time, compressive strength and workability of SAC paste and concrete, boric acid as cement retarder and polycarboxylate superplasticizer as water reducer were used for preparing SAC concrete in this study. Carbamide as fertilizer was used for making porous concrete with nitrogen nutrient releasing effect. Table 2 shows the properties of admixtures used in this research.

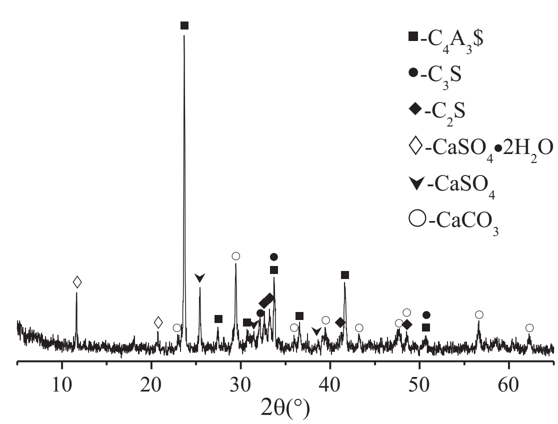

Fig. 1. XRD of SAC.

Table 2
Properties of admixtures.

Type of admixture	Properties
Retarder	99.0% from Sinopharm Chemical Reagent Co., Ltd, China
Water reducer	Solid content 25.12%, pH 6.2 and water reducing rate 28%, China Building Materials Academy
Fertilizer	99.0% from Sinopharm Chemical Reagent Co., Ltd, China

Table 1
Chemical compositions of SAC/wt%.

SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	SO_3	K_2O	Na_2O	TiO_2	SrO	Σ
9.60	21.64	2.45	45.16	1.28	10.73	0.38	0.17	1.03	0.25	92.69