



Improving the fluid transport properties of heat-cured concrete by internal curing



Shuai Nie, Wenqin Zhang*, Shuguang Hu*, Zhichao Liu, Fazhou Wang

State Key Laboratory of Silicate Materials for Architectures, Wuhan University of Technology, Wuhan, 430070, PR China

HIGHLIGHTS

- Lightweight fine aggregate (LWFA) was used to improve the performance of heat-cured concrete.
- Water absorption and chloride diffusion coefficients were tested.
- Interfacial transition zone between the LWFA and cement paste with aging was studied.

ARTICLE INFO

Article history:

Received 6 August 2017

Received in revised form 7 February 2018

Accepted 11 February 2018

Keywords:

Lightweight fine aggregate

Internal curing

Heat curing

Water absorption

Fluid transport properties

ABSTRACT

Heat curing accelerates cement hydration, leading to a coarse pore structure. This undermines the transport properties of concrete, which is essential in evaluating concrete durability. In this study, effect of saturated lightweight fine aggregate (LWFA) on the mechanical and transport properties and the microscopical characteristics of heat-cured mortar was investigated. Results show internal curing by LWFA promotes cement hydration and benefits the formation of denser hydration products and the interfacial transition zone (ITZ). This is evidenced by a reduced water absorption and chloride diffusion coefficient and an improved compressive strength at later ages. Moreover, the long-term performance of heat-cured mortar with internal curing is similar to and even better than that of the mortar cured at ambient temperature, which can be explained by the combination of the denser hydration products formed at heat curing period and the efficiency of internal curing at the subsequent curing period.

© 2018 Elsevier Ltd. All rights reserved.

1. Introduction

Precast concrete elements were widely used in the civil engineering attributed to its controllable quality and improved constructability, leading to an increasing demand. Heat curing is a common process in the precast industry to promote production efficiency by accelerating early-age hydration. However, heat curing decreases the maximum achievable degree of hydration (DOH) and compressive strength, and creates a coarser pore structure which reduce the impermeability and thus the durability of concrete as it ages [1–5]. Fluid transport property is a very important index to evaluate the service performance of concrete. However, some studies [3,6–11] have found that heat-cured concrete shows poorer fluid transport properties than that of concrete cured at ambient temperature. Efforts have been made to use different mineral admixtures to improve the fluid transport property of

heat-cured concrete while results varied [6,8,10,12–15]. D.W.S. Ho et al. [6] investigated the water absorption of heat-cured concrete incorporated with fly ash (FA), ground granulated blast furnace slag (GGBFS) and silica fume (SF), and only SF and GGBFS exhibited beneficial effect indicated by the lower sorptivity. R.D. Hooton et al. [8] and Mehmet Gesoğlu [10] found that the use of SF, metakaolin and slag can be effective in improving the chloride penetration resistance of heat-cured concrete. This positive effect of mineral admixtures is associated with the enhanced packing and secondary pozzolanic reaction leading to improved permeability of concrete [12,13]. However, heat-cured concrete has lower long-term DOH and the amount of calcium hydroxide [14,15], which may hinder the pozzolanic reaction of mineral admixtures, and result in no obvious improvement of permeability, which was observed when lower activity mineral admixture was used, e.g. fly ash [6].

Elevated temperature promotes cement hydration leading to higher DOH and porous microstructure at early stage, [16] but a significant amount of cement remains unhydrated at later stage, with the growth of age, not enough cement is hydrated to densify

* Corresponding authors at: State Key Laboratory of Silicate Materials for Architectures, Wuhan University of Technology, 122# Luoshi Road, Wuhan 430070, PR China.

E-mail addresses: wqzhang@whut.edu.cn (W. Zhang), hsg@whut.edu.cn (S. Hu).

the porous microstructure, which ultimately results in a higher permeability of heat-cured concrete than that of concrete cured at ambient temperature. Most of the researches try to improve the impermeability of heat-cured concrete by adding admixtures, ignoring the hydration potential of anhydrous cement left in the heat-cured concrete. Hence, promoting the cement hydration of heat-cured concrete is a key factor to improve its impermeability. Internal curing is an efficient way to promote cement hydration [17,18], and some results have been reported when internal curing is used to improve the fluid transport property of concrete cured at room temperature [19–23]. In this work, internal curing by lightweight fine aggregate (LWFA) is used to improve the fluid transport property of heat-cured concrete, and the water absorption, chloride ion permeability and the microstructure of interfacial transition zone (ITZ) of heat-cured concrete are investigated.

2. Materials and methods

2.1. Materials and mixture proportions

ASTM type I Portland cement, deionised water, ISO sand, and LWFA were used in this study. The LWFA, based on expanded shale, was obtained from Yichang of Hubei Province, China. The chemical compositions of cement and LWFA used in the mixture are listed in Table 1. The approximate proportions of the four main components, determined by Bogue calculation, in the cement is: $C_3S = 48.5\%$, $C_2S = 25.8\%$, $C_3A = 8.0\%$, and $C_4AF = 9.2\%$ (by mass). The results of a sieve analysis of ISO sand and LWFA are listed in Table 2. LWFA has a 24-h water absorption rate of 12.8% by dry mass (according to ASTM C128–07a). The apparent densities of the 24-h-pretreated LWFA (saturated surface dry) and the ISO sand are 1580 kg/m^3 and 2450 kg/m^3 , respectively. A polycarboxylate-type superplasticizer was added to achieve the same fluidity of mortars.

The water/cement (w/c) ratio of mortar was 0.30, and the volume fraction of aggregates in the mortar was 55% with detailed mixture proportions listed in Table 3. The amount of LWFA was calculated from Eq. (1), which was developed by Bentz et al. [21]; 42.6% of the ISO sand (on a volume basis) was replaced by saturated LWFA. The amount of water supplied by internal curing was 42 kg/m^3 .

$$C_f \times CS \times \alpha_{max} = S \times \Phi_{LWFA} \times M_{LWFA} \quad (1)$$

where C_f ($=720 \text{ kg/m}^3$) is the cement content of the mixture, CS ($=0.07 \text{ ml water/g cement}$ [24]) is the chemical shrinkage of the cement, α_{max} ($=0.83$) is the expected maximum DOH, Φ_{LWFA} ($=12.8\% \text{ kg water/kg dry LWFA}$) is the absorption capacity of the LWFA used (24-h absorption value), and S ($=1$) is the expected degree of saturation of the LWFA expressed as a function of the assumed absorption value, M_{LWFA} (kg/m^3) is the mass of LWFA.

The 100%IC indicates the pre-wetted LWFA added into the mortar can supply 100% of the amount of internal curing water, which is calculated from Eq. (1), while the 50%IC means that the pre-wetted LWFA added into the mortar can only supply 50% of the amount of internal curing water.

2.2. Specimen preparation and curing regimes

The mortars were mixed and cast at room temperature (25°C). The mortar prisms ($4 \text{ cm} \times 4 \text{ cm} \times 16 \text{ cm}$) were prepared to test the compressive strengths. Cylinders of the mortars ($\Phi 100 \text{ mm} \times 200 \text{ mm}$) were prepared to test the transport properties. During the delay period before steam curing, the specimens were covered with polyethylene sheets and kept at 25°C for 3 h. The maximum temperature during steam curing was 55°C and the heating rate was 15°C/h . The duration for which heat curing was performed at 55°C was 4 h. Then, the temperature was lowered to room temperature at a cooling rate of 15°C/h . After being heat cured, the specimens were removed from the moulds and stored indoors under a controlled temperature and relative humidity (T: $25 \pm 3^\circ\text{C}$, RH: $70\% \pm 5\%$). Control mortar specimens were immediately placed in a mist room with temperature at 20°C and RH $> 95\%$ after being cast. After 1 day, the control mortars were demoulded and also stored indoors with the heat-cured mortars.

2.2.1. DOH

The DOH was determined from the amount of chemically bound water. Three samples ($4 \text{ cm} \times 4 \text{ cm} \times 4 \text{ cm}$) cut from the mortar prisms were crushed to powders passing through the 1.18 mm sieves, such that the error caused by the uneven distribution of the fine aggregate was reduced. The samples were dried in an oven at 105°C for 24 h to remove the evaporable water, and then heated at 1050°C for 3 h to remove all the chemically bound water. The amount of chemically bound water was calculated as the mass loss between 105°C and 1050°C with the loss from the heating of the dry cement, ISO sand, and LWFA accounted for. The ratio of the amount of chemically bound water to the DOH was assumed to be constant at 0.25 [25].

2.2.2. Water absorption test

The amount of water absorbed by mortar is closely related to its porosity and the pore connectivity, which significantly influences the permeability and durability of cementitious materials. The water absorption test was performed according to the ASTM C 1585 standard. Cylindrical specimens were cut into disks with a length of $50 \pm 2 \text{ mm}$ and placed in an environmental chamber for 3 days with the temperature and RH at $50 \pm 2^\circ\text{C}$ and $80 \pm 3\%$ respectively. After the 3-day period, the specimens were conditioned at $23 \pm 2^\circ\text{C}$ for 15 days to ensure the equilibrium in moisture distribution. Before the absorption test, the initial specimen weight was recorded, and the lateral surface of the test specimen was sealed with the aluminium tape and the top unexposed surface was sealed with a polyethylene sheet.

The absorption is calculated by using Eq. (2)

$$I = \frac{m_t}{a \times \rho} \quad (2)$$

where I is the absorption (mm), m_t is the change in the specimen mass over time (g), a is the exposed area of the specimen (mm^2) and ρ is the density of water (g/mm^3).

The initial and secondary rates of water absorption ($\text{mm/s}^{1/2}$) are defined as the slope of the line by the least squares regression for the plot of I against the square root of time ($\text{s}^{1/2}$) [26]

Table 1
Chemical compositions of the cement and LWFA used (% by weight).

	SiO ₂	Al ₂ O ₃	Fe ₂ O ₃	CaO	MgO	K ₂ O	Na ₂ O	Loss
Cement	21.72	4.92	3.01	62.14	2.27	0.65	0.22	1.78
LWFA	65.46	16.75	7.63	1.08	2.43	3.82	0.94	0.27

Download English Version:

<https://daneshyari.com/en/article/6714907>

Download Persian Version:

<https://daneshyari.com/article/6714907>

[Daneshyari.com](https://daneshyari.com)