Construction and Building Materials 154 (2017) 752–762

Contents lists available at ScienceDirect

Construction and Building Materials

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

An original test method to assess water absorption/desorption of lightweight aggregates in presence of cement paste

Latifou Bello [a,*], Eric Garcia-Diaz [b], Patrick Rougeau [c]

[a] International Institute for Water and Environmental Engineering, Ouagadougou, Burkina Faso
[b] Centre des Matériaux des Mines d'Alès, Ecole des Mines d'Alès, Alès, France
[c] Centre d'Etudes et Recherches de l'Industrie du Béton, Épernon, France

HIGHLIGHTS

- This study proposes an original test method to assess absorption/desorption in cement paste at a given time during the dormant period.
- The test method allows to evaluate the effective water to cement ratio in cement paste.
- The results show that the water absorption by LWA decreases water to cement ratio and workability whereas the desorption increases them.
- Fresh paste absorption of 30 min seems to be a good value to accurately estimate the water demand of LWA in cement paste during mixing and placing.

ARTICLE INFO

Article history:
Received 19 February 2017
Received in revised form 29 June 2017
Accepted 31 July 2017

Keywords:
Test method
Water absorption in cement paste
Desorption
Effective water/cement ratio
Lightweight aggregates
Workability

ABSTRACT

The calculation of the effective water content in lightweight aggregates concrete is not easy because of possible water transfer from fresh cement paste to porous aggregates at an early stage (dormant period). A method to quantify and follow this phenomenon is proposed. The absorption method consists in mixing partially saturated lightweight aggregates with fresh cement paste of a given water/cement ratio. At a given time during the dormant period, lightweight aggregates and fresh cement paste are mechanically separated. Then a water balance is made through weighing procedures before and after thermal treatment to evaporate the physically bound water. For unsaturated lightweight aggregates, a transfer of water from the paste to aggregates is observed while for saturated aggregates the transfer is from the aggregates to the paste. The kinetic and the asymptotic absorption values are decreasing functions of the water/cement ratio. Fresh paste absorption of 30 min seems to be a good value to estimate the water demand of lightweight aggregates based on initial dried aggregates to obtain an efficient mixing and workability stability at early stages.

1. Introduction

The structural lightweight concrete (LWC) is a high performance material with good thermal insulating characteristics and good mechanics properties [1]. The granular skeleton of this kind of concrete incorporates all or part of mineral lightweight aggregates (LWA). These LWA are porous aggregates with high porosity. D. Zhang et al. [2] observed that expanded clay and expanded shale aggregates have porosity from 34 to 75%. LWA have a low particle relative density due to the cellular pore system. According to ACI 213 R-03 [3], the practical range of coarse LWA relative densities is from almost 1/3 to 2/3 that for dense natural aggregates (DNA).

As a result of their high porosity, LWA have generally high water absorption. T. Holm et al. [4] observed that the water absorption depends on the pore size, continuity and distribution. The 24 h absorption of LWA ranges from 5 to 15% by mass of dry aggregates [5]. J. Castro et al. [6] reported that the typical 24 h water absorption of fine LWA is observed to vary between 6 and 31% . In contrast, most DNA will absorb less than 2% of moisture, according to ACI 213R-03 [3].

The high porosity and water absorption of LWA have implications for mix design, fresh, mechanical and durability properties of LWC [7]. The problem is the absorption of water from the fresh mix into the porous aggregates, which makes uncertain the prediction of the water demand and in consequence the effective water/cement ratio [8]. That is why mix proportioning of lightweight concrete is generally less accurate than that of the dense natural aggregates concrete (DNC) [8]. When water is added to the dry por-

* Corresponding author.
E-mail address: l.bello@laposte.net (L. Bello).

http://dx.doi.org/10.1016/j.conbuildmat.2017.07.236

ous aggregates, part of the mix water is absorbed by aggregates before the cement begins to set. Water absorbed by the LWA before setting is not considered to be part of the effective water to cement ratio of a given concrete mixture [9,10]. Due to the difficulty of anticipating and controlling the amount of absorbed water, it is not easy to calculate the effective water content [11]. However, when LWA are adequately prewetted, there is a minimal amount of water absorbed during mixing and placing, according to ACI 213R-03 [3].

The LWC requires a specific mix design method that is quite different from DNC. Using conventional mix design method would give rise to the material segregation as well as the lower strength by the lightness and high absorption of LWA [12]. The ability of the dried LWA to absorb large quantities of water can lead to early tightening of LWC at the fresh state with a loss of workability [13]. According to M. Zhang and O. Gjorv [14] and F. De Larrard [15], in practice, to limit this loss of workability, the LWA were presoaked, coated or were used at saturated and dry surface state. ACI 211.2–98 [16] observed that wet aggregates are preferable to dry aggregates as they tend to absorb less water during mixing and therefore reduce the possibility of loss of workability as the concrete is being mixed, transported and then placed.

The difference in density between the cement paste and lightweight aggregates (LWA) tends to favor the segregation [17]. T. Lo et al. [18] reported that if the viscosity of the mortar is high enough, the coarse LWA are restrained by the mortar, thus avoiding segregation. The level of viscosity is strongly dependent on the initial water available for the cement paste and also indirectly dependent on the water absorbed by porous aggregates during the mixing and the dormant period [15].

The absorption or otherwise of water and or cement paste by LWA according to their porosity and saturation degree affects the microstructure of hardened lightweight concrete (LWC). Although LWA is more porous compared to DNA, the interfacial zone microstructure between the LWA and mortar matrix appears to be denser [19] probably due to the absorption of water by the dry LWA [20]. At fresh stage, dry LWA absorb water from fresh cement paste and so reduce water/cement ratio of its surrounding cement paste, according to them. At later stages, part of the water contained in the LWA was gradually released toward the matrix, which improved hydration process. This observation confirmed previous findings by M. Zhang and O. Gjorv [21].

When presoaked LWA were partially substituted in dense natural aggregates concrete (DNC), they provided an internal source of water which could be consumed by cement hydration during hardening [10,22–24]. This internal concrete cure has several consequences in terms of cracking and durability [25]. R. Henkensiefken et al. [10] reported that the addition of saturated lightweight aggregates as an internal curing agent increases the degree of hydration and produces a denser microstructure.

The experimental curves of water absorption by lightweight aggregates (LWA) and dense natural aggregates (DNA) was plotted in Fig. 1. A marked difference in the absorption kinetics of both aggregates indicated that early stage absorption of LWA is higher than that of DNA. According to ACI 211.2–98 [16], the principal factors necessitating modification of proportioning and control procedure for lightweight aggregates concrete (LWC), compared with dense natural aggregates concrete (DNC), are the higher absorptions and the higher rates of absorption of the most lightweight aggregates (LWA). In practice, when dry LWA were used, the added water was adjusted on the basis of the 24 h water absorbed by LWA. As the absorption kinetic of dry LWA was lower than the time of mixing, one part of the added water did not penetrate aggregates after mixing. This fact could lead to segregation and inaccuracy in the estimation of the effective water. A. Neville [11] observed that high amount of water added to formulate LWC may cause segregation, with the light large aggregates floating on top. Moreover, the addition of excess water will result in higher porosity, lower strength and lower durability, according to E. Bescher et al. [26]. That is why the NF EN 206/CN [27] recommended that the water absorption of coarse LWA in the fresh concrete shall be taken as the value obtained at 1 h based on the method given in Annex C of NF EN 1097–6 [28], using the as-used moisture state in place of the oven-dry state instead of the 24 h water absorption value.

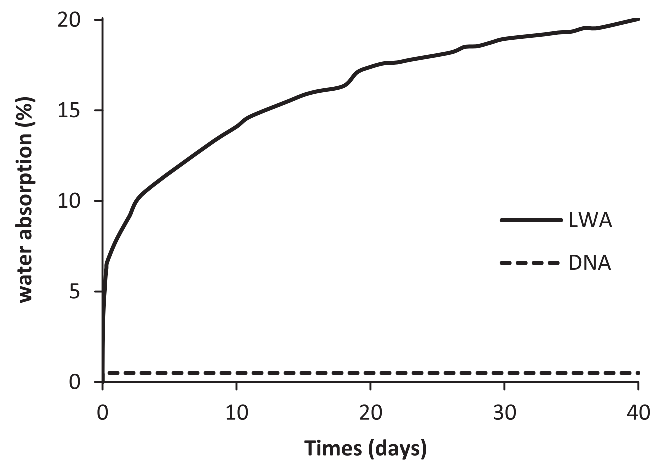

Fig. 1. Water absorption of LWA and DNA during 40 days.

The effective water/cement ratio depends on the rate of water absorption of LWA in cement paste at the time of mixing. Only limited information is available on the value of water/cement ratio to take account of the kinetic absorption of LWA in cement paste to design LWC. The standard methods [28,29] and alternative methods [30,31] based on absorption in water test can lead to an overestimation of water/cement ratio at a very early stage.

The aim of this paper is to develop a new test method to evaluate the water absorption of LWA in cement paste versus time in order to have a better estimation of the effective water/cement ratio and improve rheological, mechanical properties and durability of LWC. The detailed testing procedure of the new method is illustrated. Firstly, the test is validated on DNA and LWA. Secondly, the effect of initial water content of LWA on workability of fresh aggregates/cement paste mix is described and analyzed.

2. Materials and methods

2.1. Materials

A French Portland cement of type CEM I 52,5N (PC) with a specific density of 3 160 kg/m^3 was used for the pastes. Chemical compositions and physical properties of cement are shown in Table 1.

Siliceous coarse aggregates (DNA) and clay expanded coarse aggregates (LWA) with a maximum size of 8 mm were used for the absorption test in the presence of fresh cement paste and slump flow test. The particle size distribution of aggregates is shown in Fig. 2. Table 2. gives characteristic properties of these aggregates. Water absorptions and specific density were tested according to NF EN 1097–6 [28].

2.2. Fresh aggregates/cement paste mix for new absorption test

The aggregate absorption test in the presence of cement paste is realized on fresh aggregates/cement paste mixes according to the new test method described in paragraph 3. Several pastes with different water/cement ratios of 0.3, 0.4, 0.5 and 0.6 are used. The compositions of the fresh aggregates/cement paste mixes are shown in Table 3. The new test method was performed to obtain the water absorption in cement paste at different time intervals (5, 15, 30, 60 and 120 min). A fraction of 60% of the aggregate volume was kept constant for all water/cement ratios.