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The effect of lightweight aggregate water absorption on the reduction of water-cement ratio in fresh concrete

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Abstract

The aim of this paper is to present the problem of water-cement ratio reduction in structural lightweight concrete as a result of mixing water absorption by the lightweight aggregate. The research was carried out on eighteen concrete mixtures made of sintered fly ash aggregate and cement pastes of different nominal water-cement ratios. It has been demonstrated that the rate and the extent of the absorption of mixing water by the aggregate in concrete is dependent not only on its water absorption, but also on its moisture content, moisture state, the procedure of concrete preparation and the concrete composition. Moreover, it has been proved that the standard method for calculation of the so-called effective water-cement ratio is accurate only in the case of high initial moisture content of the lightweight aggregate. When dry sintered fly ash aggregate is used, the standard method gives underestimated values of the ratio as compared to its actual values determined in tests.

The effect of mixing water absorption by the lightweight aggregate, revealed in tests of fresh concrete as the reduction of water-cement ratio, was also reflected in hardened state of concrete as the increase of its strength. The strength increase was higher for mixtures with higher content of lightweight aggregate. Although the porous aggregate is the weakest element in structural lightweight concrete, in this case its higher content may be compensated with excess by the stronger cement matrix resulting from the reduction of water-cement ratio.

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Keywords: Lightweigth aggregate; lightweigth aggregate concrete; initial moisture content, water-cement ratio; water absorption

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Nomenclature

c	cement content
LWA	lightweight aggregate
LWAC	lightweight aggregate concrete
mc	moisture content of LWA
w	mixing water content
w_{eff}	effective water content
WA_{max}	maximum water absorption of LWA in time, specified according to EN 1097-6
WA_t	water absorption of LWA after time *t*, specified according to EN 1097-6
w/c	water – cement ratio
$(w/c)_{eff}$	effective water – cement ratio

1. Introduction

The water-cement ratio is deemed to be one of the most important factors deciding the strength and durability of hardened structural concrete. It is easy to establish the ratio value as long as the aggregate cannot absorb mixing water from fresh concrete. Generally, in the case of lightweight aggregate concrete (LWAC), due to high water absorption of the porous aggregate, the actual water-cement ratio is usually lower in comparison to its nominal value, and it is difficult to determine. There are a lot of factors influencing the actual water-cement ratio of lightweight aggregate concrete mixtures. The most important are: water absorption of lightweight aggregate in time, moisture content of lightweight aggregate, the state of moisture content in lightweight aggregate and the volume share of porous aggregate in concrete. Rheological properties of cement paste are additional parameters which can affect the actual value of LWAC water-cement ratio.

The reduction of water-cement ratio in fresh concrete is usually regarded as a negative phenomenon as it can lead to loss of the mixture workability. As a result, in many cases the aggregate to be used in LWAC is saturated with water as it protects the fresh concrete from the *w/c* reduction and in consequence from the loss of mixture workability. Nevertheless, such treatment may deteriorate the properties of hardened concrete, especially concrete durability, which was proved e.g. in [1, 2, 3]. The worst solution used to eliminate the loss of mixture workability is dosing additional water directly into the mixture, apart from the mixing water, in the amount corresponding to water absorption of the aggregate, yet during the period of time longer than 1 – 2 hours. In many cases of LWAC the additional portion of water is equal to the water absorbed within 24 or 48 hours (WA_{24h}, WA_{48h}) or even to WA_{max}. In such situation the aggregate is unable to absorb all the excessive water while the mixture is still in the fresh state. That leads, in turn, to a higher *w/c* than was assumed and always results in lower strength and durability.

On the other hand, the absorption of water by aggregate from fresh concrete may enhance adhesion of cement paste to the aggregate and thus the tightness of hardened concrete. It can result in higher strength and better durability of concrete, which was revealed in some research [4, 5, 6]. As a result, some guidelines for making LWAC recommend using dry aggregate or the one with initial moisture limited to the amount of water that will be absorbed by the aggregate within 30 minutes up to 1 hour.

1.1. Mechanism of water absorption by lightweight aggregate in fresh concrete

The maximum water absorption (WA_{max}) of lightweight aggregate may vary from a few percent up to 45 %, depending on the aggregate pore structure. Generally, the higher water absorption of lightweight aggregate and the lower initial moisture content of the aggregate, the bigger the reduction of water-cement ratio in fresh concrete.

Nevertheless, it should be noted that the absorption of water by aggregate in pure water and in fresh concrete differs. As shown by Smeplass, Sandvik and Hammer [7, 8, 9], depending on rheological properties of the cement