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# A new methodology for determining water absorption of lightweight, normal-weight and heavyweight aggregates in a viscous medium

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## HIGHLIGHTS

- To produce LWAC, the tendency is to saturate the LWA to minimize the absorption.
- A new methodology to determine the aggregates absorption in concrete is proposed.
- Viscous absorption is recommended for accuracy in the concrete dosage.

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## ABSTRACT

Water absorption in aggregates has important effects on the properties of concretes especially in lightweight aggregate concretes (LWAC). It is assumed that during the production of LWAC the lightweight aggregate (LWA) absorption is equivalent to a certain percentage of the absorption determined in an aqueous medium. A new procedure for determining the absorption by aggregates in concrete (viscous medium) is proposed. This methodology makes possible to determine the water absorption in a viscous medium and it allows specifying accurately the amount of mixing water to produce concretes.



## 1. Introduction

The porous structure of aggregates has a significant influence on several of their physical properties—water absorption and density—and mechanical properties—deformation—. The physical and mechanical properties of concrete produced with such aggregates will be similarly affected.

Water absorption also has an effect on the fresh state of concrete especially in lightweight aggregate concrete (LWAC) [1,2]. If the appropriate measures are not taken the water absorption has a noticeable effect on some characteristics of LWAC, in particular on its workability [3]. During the production of LWAC, there are different views as to the degree to which the lightweight aggregates (LWA) should be pre-wetted, that is, the amount of water content in the LWA (absorption) during the production of concrete. In fact, some researchers hold that the appropriate way to produce LWAC is to use the LWA completely saturated, while others opt for partially saturated LWA [3,4].

In normal-weight concrete (or other porous material) the physical and mechanical properties depend, among other variables, on the water content (high water content implies less mechanical performance and vice versa) [5,6]. It would be logical to assume that LWAC should do the same. Therefore, in order to improve the physical and mechanical properties of LWAC the water content in LWA should be reduced to the minimum level which still enables workability to be maintained at an acceptable level.

In addition, in LWAC there is also a discrepancy regarding the amount of water absorbed between the time of mixing and the laying of the concrete [7,8]. It is assumed that in this period the absorption of the LWA is equivalent to a certain percentage of the absorption determined according to the standard test used.

The aforementioned facts have led us to conclude that there are two kinds of absorption: absorption in an aqueous medium and absorption in a viscous medium. The first type would correspond to the absorption of the aggregates prior to their mixing in the concrete, while the second would correspond to the absorption of the aggregates that takes place in fresh concrete, particularly between the mixing and the laying.

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### 1.1. Background

In the production of LWAC, the general tendency is to pre-wet or saturate the LWA to minimize the water absorption between the moment of mixing and the laying [5]. If the aggregates are dry when they are placed into the concrete mixer, they absorb water quickly and the workable concrete mixtures become stiff within a few minutes of mixing [9,10]. Therefore, when the concrete is produced with a LWA having a high rate of absorption but low initial moisture content, it is convenient first to mix the aggregate with at least half of the mixing water, and only then add cement to concrete mixer [11]. LWA can absorb a significant amount of water during the mixing, which causes an increase in the density of the concrete and a decrease in its value of thermal insulation. In some cases, the absorbed water may represent up to 25% of the weight of the aggregate; this mass of water does not contribute to the workability of the LWAC [12].

H. Weigler and S. Karl [13] state that between mixing and laying the concrete there is an absorption which corresponds with sufficient accuracy to the absorption of the LWA for 30 min in aqueous medium. Other authors indicate that the total water absorbed during the mixing corresponds to the absorption of the LWA in 60 min [14,15]. Other authors suggest that the absorption of water by LWA in fresh concrete represents between 75 and 100% of the corresponding absorption in an aqueous medium during a 30 to 60 min period [16]. However, according to some authors water absorption between 30 and 60 min is insignificant [17].

The difficulty of transporting LWAC comes from the absorption capacity of LWA. If transport time is prolonged, LWA will absorb some of the water from the mortar, causing the concrete to become rigid. This stiffness is more pronounced if the LWA is dry and absorbent. A small amount of mixing water in the mortar produces a great sensitivity to water loss [18]. The reduction of the water/cement ratio (w/c) in fresh concrete is generally considered a negative phenomenon, since it can lead to a loss of the mixture's workability [19]. Zhu, C. et al. [7] report on the lack of studies concerning the degree of saturation of the LWA that causes the limited use of LWAC.

However, A. Bogas et al. [8], approach the aforementioned problem from a different perspective and although there is some similarity to our proposal, our study develops a new methodology. Their approach is based on the determination of the absorption of the mortar and concrete by means of the manual cleaning of the mortar and concrete with a cloth.

The loss of workability of LWAC is commonly accepted to be due to the decrease of mixing water as a consequence of the absorption by the aggregates [2]. However, this position and its commonly adopted solution—the pre-saturation of the LWA—does not address the reality of the problem. In normal-weight concrete, the amount of water in and surrounding the aggregates is corrected to respect the w/c and the workability. Therefore, LWAC should be treated equally in this respect. However, the LWAC research corpus does not propose increasing the water corresponding to the absorption of the LWA between the time of mixing and the laying, instead the pre-saturation option is adopted.

### 1.2. Water absorption of lightweight aggregates

The determination of the water absorption of the aggregates is currently carried out according to the standard UNE-EN 1097-6 [20], hereinafter referred to as aqueous absorption, because the test is performed in an aqueous medium. Such a procedure leads to greater absorption rates than real ones, especially in LWA. Indeed, the subjectivity of the test leads to two important anomalies [21]:

a. The first anomaly relates to the randomness in the drying of aggregates: there is no absolute guarantee of complete aggregate surface drying. The same operator, or different operators, according to the intensity and duration of drying with the air dryer and by drying the surface of the aggregates with a cloth, can obtain different results.
b. The second anomaly concerns the determination of absorption level in aggregates. This is important to be aware that removing the moisture coating on the surface (surface absorption) can affect the aqueous absorption result.

In addition, the current practice which consists of pre-wetting the aggregates and considering the absorption produced by them in fresh concrete as a percentage of the water absorption obtained in the aqueous medium. Such a procedure can lead to estimate a higher water content of the aggregates than actually present and this would affect the physical and mechanical properties of the concrete produced.

All these considerations lead us to believe that the water absorption of the aggregates in the fresh concrete takes place in a viscous medium (fresh concrete), and not in an aqueous medium. Such viscous water absorption should be less than that obtained in an aqueous medium.

In order to overcome these disadvantages discussed in both aforementioned anomalies, the authors have proposed a methodology for determining the absorption of the aggregates in an aqueous medium [21], and the present work proposes a new methodology for determining the water absorption of the lightweight, normal-weight and heavyweight aggregates in a viscous medium. These two procedures minimize the manipulation and increase the precision of the results, obtaining a real absorption (in aqueous or viscous medium). In addition, there is no interference of the surface water and there exists the possibility to choose the duration of the test. The first absorption can be determined in short times—between 1 and 2 min for the aqueous absorption and between 7 and 10 min for the viscous absorption.

### 1.3. Objectives

In this work, we intend to dissociate the use of the two types of absorption: Firstly, the aqueous absorption is to be used for determining the capacity of the absorption of the aggregates in a time slot and strictly informative. The aqueous absorption result is used as a reference to correct the contribution of water in the aggregates of a concrete mixture. Secondly, the viscous absorption is used for determining the actual amount of absorption under the real conditions present during concrete placement.

## 2. Theoretical foundation

All concrete is composed of cement, water, air, sand and gravel. Both aggregates can be lightweight, normal-weight or heavyweight. The sum of each volume component must equate to one cubic meter of concrete, which is the basis of all concrete dosage. Obviously, additives and additions may also be part of concrete but we will not consider them for this study because they do not affect the proposed method.

The volume of the unity cubic meter of fresh concrete ($V_0$), or the concrete reference mould volume ($v_0$), is modified between the mixing and the laying depending on the moisture content of the aggregates before mixing. The volume variation is related to different parameters and the repercussion of some of them can be insignificant and they produce a decrease of the concrete volume (hereinafter referred to as "differential Volumetric ($\Delta v$)"), which will be described in Section 2.3. For determining $\Delta v$ a