DETERMINATION OF THE EFFECTIVE COMPOSITION OF LWA CONCRETES

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ABSTRACT

The article describes a method for determination of the effective composition of lightweight aggregate concrete. The mix water absorption of the porous aggregates may be calculated from the volume reduction in the the fresh concrete, regarding the difference between density of the proportioned receipe and the measured density of fresh concrete. A method for determination of dry particle density of porous aggregates by a pycnometer method is also described. By replacing water by a non water soluble fluid the SSD situation for the aggregates can be identified.

Key words: *LWA concrete, water absorption, effective composition, dry particle density*

INTRODUCTION

Ordinary light weight aggregates (LWA) may absorb significant amounts of mix water during the fresh phase of the LWA concrete. This effect is not only a problem with respect to slump loss, it also complicates the specification and documentation of light weight aggregate concretes; what is the effective water/binder ratio?

A common way of handling these problems has been to saturate the aggregates either before mixing, or in the mixer. However, such efforts both complicate the mixing process and reduce the technical potential of the concrete. As the effective w/(c+s)-ratio no longer benefits from the mix water absorption, both strength and durability properties are negatively affected. In addition, the concrete density is normally increased significantly more through presaturation of the aggregates than through natural mix water absorption using dry aggregates.

Consequently, control and utilization of the mix water absorption may be a more attractive solution than a total elimination of this effect.

CALCULATION OF THE MIX WATER ABSORPTION

The mix water absorption of the LWA aggregates causes a general volume reduction in the fresh concrete. This volume reduction is reflected in a general increase in concrete density. Hence, the total mix water absorption may be calculated from the difference between obtained density and the nominal density of the concrete, assuming a nominal density calculated from the nominal mix proportions. In order to simplify the calculation, we have chosen to base the nominal density on the dry particle densities of the constituents. Possible initial moisture of the aggregates are also included calculating the nominal density.

The correlation between the mix water absorption and the difference between nominal and observed densities is also reliant on the presumption that only insignificant amounts of cement particles, silica fume particles or aggregate fines are absorbed into the coarse LWA aggregates with the water. The validity of this premise has been investigated by systematically comparing the dry particle density of LWA aggregates sieved from fresh concretes based on saturated aggregates and dry aggregates, respectively. The results from this investigation indicate that the amount of particles absorbed into LWA aggregates is negligible /1/.

All calculations are performed in a PC worksheet, developed for this purpose. The procedure is divided into three separate steps.

Step 1. Data input

The input data are;

* Measured concrete density
* Measured air content of the fresh concrete
* Proportioned recipe
* Dry particle densities
* Initial moisture of the aggregates

The input area of the worksheet is shown in table 1.

WATER ABSORPTION IN LWA CONCRETE VS2.2 SS/TN
Date:....1991-02-05
Recipe:..Leca-5 %   Project:651983.27

Measured values, fresh concrete
Measured density (kg/m^3):.   **1865**
Measured air content (%):..   **2.9**

Proportioned recipe

Constituents	Mass (kg)	Dens. (kg/dm^3)	Volume (dm^3)	Moisture (%)
Cement	**479**	3.15	152.1	
Silica	**37**	2.20	16.8	
Water	**187**	**1.00**	187.0	
Initial moisture	28			
Sand 0-8 mm	**600**	**2.65**	226.4	
Leca 4-8 mm	**265**	**1.23**	215.4	5.3
Leca 8-16 mm	**279**	**1.27**	219.7	5.0
Superplasticizer	**6.0**	1.20	5.0	
Sum	1875.0		1017.4	
Assumed air content	20.0		20.7	
Total volume			1038.2	

Table 1. Input data for calculation of the effective composition of LWA concretes. Active parameters are printed bold. Worksheet printout

Step 2. Initial volume correction of nominal recipe

The nominal recipe is found by correcting the proportioned recipe with respect to devations from unit volume (1 m^3) and observed air content.

The air volume of the proportioned recipe are adapted to the measured air content of the fresh concrete by demanding;

$$\frac{l_0'}{m_0} = \frac{l_m}{V_m \cdot \rho_m}$$

l_0 - *corrected proportioned air content* (m^3/m^3)
l_m - *measured air content* (m^3/m^3)
V_m - *unit volum* (m^3)
ρ_m - *measured density* (kg/m^3)

Proportioned recipe corrected with respect to devations from unit volume (1 m^3) and observed air content are now found by multiplying the volumes of each constituent by a correction factor k_1:

$$k_1 = \frac{V_m}{V_0 + l_0}$$

V_0 - *proportioned volume, exclusive air content* (m^3)

The air content of the nominal recipe, l_k are:

$$l_k = l_0 \cdot \frac{V_0}{V_0 + l_0}$$

Step 3. Calculation of mix water absorption and final correction of recipe

The absorbed volume is calculated on the basis of a constant total mass, and an increased density:

$$V_{abs} = \left(1 - \frac{\rho_0}{\rho_a}\right) V_m$$

V_{abs} - *absorbed volume* (m^3)
ρ_0 - *nominal density* (kg/m^3)
ρ_a - *observed density* (kg/m^3)

Nominal recipe corrected with respect to water absorption are found by multiplying the volumes of each constituent (including the air content l_m, excluding the absorbed water) by the a correction factor k_2:

$$k_2 = \frac{V_m + V_{abs}}{V_m}$$

Finally, the effective w/(c+s)-ratio is calculated. The worksheet output area are shown in table 2.

The accuracy of the calculation depends solely on the accuracy of the input parameters. The calculation principle itself is exact, except for the presumption that no particles are absorbed with the water.

Effective composition of LWA concrete

Constituents	Mass (kg)	Density (kg/dm³)	Volume (dm³)	Moisture (kg)	Assumed abs (weight %)
Cement	476.4	3.15	151.3		
Silica	36.8	2.20	16.7		
Water	145.0	1.00	145.0		
Absorb water	41.0				
Initial moisture	27.8				
Sand 0-8 mm	596.8	2.65	225.2		
Leca 4-8 mm	263.6	1.23	214.3	14.0	7.6
Leca 8-16 mm	277.5	1.27	218.5	13.9	7.6
Superplasticizer	6.0	1.20	5.0		
Sum	1865.0		971.0	27.8	
Measured air content			29.0		
			1000.0		

Calculation of water absorption i LWA

Teoretical absorption:.......	41.0 kg
"Measured" absorption:.......	41.0 kg
Nominal v/(c+s):...........	0.36
Nominal paste content (%):...	34.3
Effective v/(c+s):...........	0.28
Effective paste content (%):.	31.3

Estimated dry concrete density

Hydration ratio of cement:...	0.4
Pozzolan activity of silica:.	0.8
Dry concrete density (kg/m³):	1703

Table 2. Effective composition of the LWA concrete, assuming that only water has been absorbed

The impact of input parameter deviations are shown in table 3. As can be seen, the calculations are sensitive to deviations in measured air content, measured concrete density, initial LWA moisture and measured dry particle density. In general, an overestimated mix water absorption may be the result of;

* measured air content too high
* measured density too high
* measured initial LWA moisture too low
* measured particle densities too low

Initial LWA moisture and fresh concrete density are easily determined with a sufficient accuracy. However, some uncertainty are connected to the determination of the air content and particle densities.

In general, the validity of the pressure method for the determination of the air content of LWA concretes may be questioned. So far, the results indicate that this method is fully acceptable for high strength concretes containing natural sand, but probably less adequate for LWA concretes including LWA sand. At the moment, alternative methods are being evaluated.

Dry particle densities of LWA aggregates can not be determined directly by the use of ordinary water pycnometer methods, as the aggregates absorb water during the test procedure. On the other hand, saturated densities are not easily determined either, as the open porosity of the aggregate surfaces complicates the identification of the SSD situation. As an alternative, mercury porosimetry has been utilized, providing fully acceptable results. However, both from a practical and environmental point of view, this method may be less applicable than ordinary pycnometer methods. Consequently, the water pycnometer method has been modified in order to accomplish the determination of dry particle densities of light weight aggregates.

DETERMINATION OF DRY PARTICLE DENSITIES BY A MODIFIED PYCNOMETER METHOD

The problem of identifying the SSD situation for light weight aggregates may be solved by replacing the pycnometer water by a non water soluble fluid, preferably with a specific gravity higher than water, but lower than the water saturated aggregate particles. This alternative pycnometer fluid should also be able to displace all free water surrounding the particles, leaving no menisci. According to our experience, 1-1-1 trichlorethane fulfills this requirements.

The following procedure has been developed:

Solid density:

* A two-pipe pycnometer is calibrated with destilled water
* Oven dry aggregate of known mass are placed in the pycnometer and vacuum saturated with destilled water
* The pycnometer is filled by destilled water and weighed

Particle density:

* Two thirds of the free water is replaced by trichlorethane
* The pycnometer is shaked heavily in order to displace the free water on the aggregate surfaces. The fluids are then allowed to separate during the next 12 hours

* The remaining water is replaced with trichlorethane. Any remaining water on the particle surfaces may easily be detected as a ligth shimmering due to the light refraction at the water/trichlorethane boundary surface.

The calculations are performed in a PC worksheet, dividing the procedure into two steps:

Step 1. The solid density of the aggregates

The solid density is given by:

$$V_f = V - \Delta V = \frac{m_w - m_{nw} - m_t}{\rho_w}$$

$$\rho_f = \frac{m_t}{V_f} = \frac{m_t}{m_t - (m_{nw} - m_w)} \cdot \rho_w$$

V_f - *solid volum of LWA* (m^3)
ΔV - *volume of pycnometer fluid* (m^3)
m_t - *dry mass of LWA* (kg)
m_{nw} - *net mass of pycnometer with LWA / water* (kg)
m_w - *net mass pycnometer with water* (kg)
ρ_w - *density of water* (kg/m^3)
ρ_f - *solid density* (kg/m^3)

Step 2. Particle density and porosity

The particle density is given by:

$$V_t = V - \Delta V = \frac{m_w}{\rho_w} - \frac{m_{nt} - m_{nw}}{\rho_{tri} - \rho_w}$$

$$\rho_t = \frac{m_t}{V_t}$$

V_t - *particle volume of LWA* (m^3)
V - *volume of pycnometer* (m^3)
m_{nt} - *net mass pycnometer with saturated LWA / trichlorethane* (kg)
ρ_{tri} - *density of trichlorethane* (kg/m^3)

The available porosity, *p*, is given by:

$$p = (1 - \frac{\rho_t}{\rho_f})$$

The modified pycnometer method is relatively sensitive to measuring errors /1/. However, the obtained results for particles > 1mm corresponds almost perfectly with results obtained with the mercury pycnometer. The deviations obtained reproducing the tests has been less than 2 %. The density of particles less than 1 mm have also been determined, but these results are less reliable because of a tendency of flocculation of particles as the water is displaced by trichlorethane.

PRELIMINARY EXPERIENCE AND CONCLUSIONS

The preliminary results indicate that it is possible to determine the effective composition including the water/binder ratio of light weight aggregate concrete with acceptable accuracy and reproduceability under laboratory conditions. In general, the correlation between calculated mix water absorption and observed slump loss is good.

Hence, the present method may be a valuable tool planning and performing LWA concreting. However, it is an open question whether this method is suitable for documentation of concretes in full scale production. Variations in aggregate density and aggregate moisture may disturb the calculations, if these variations are not detected through intensive control routines.

So far, the method has proven to be a useful tool developing new LWA concretes with extreme strength/density ratios. Examples of typical achieved information are shown in Figures 1 and 2.

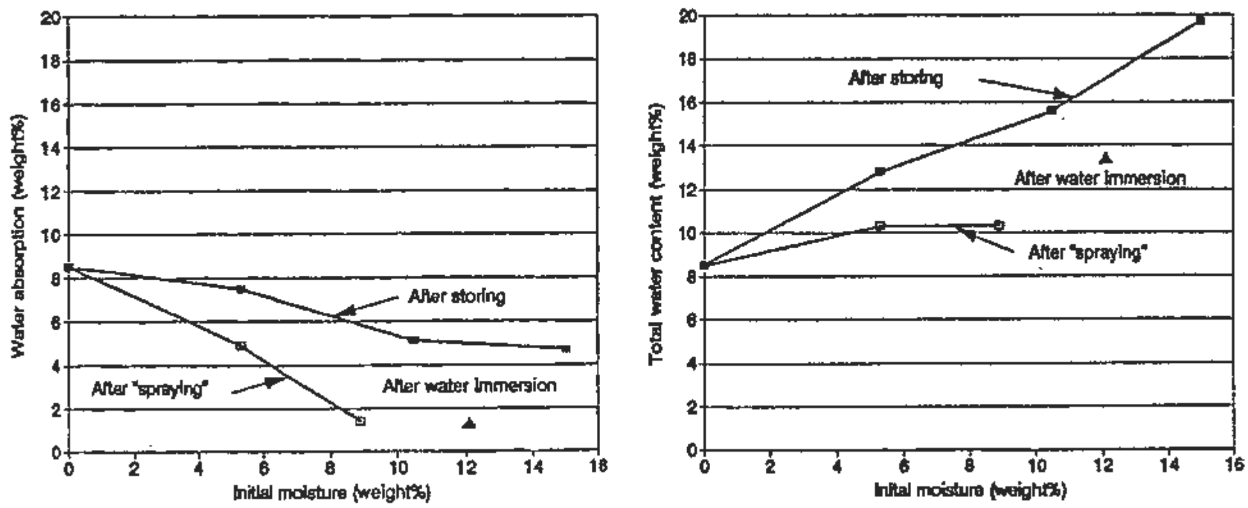

Figure 1. Effect of the initial LWA moisture on the mix water absorption (example)

Figure 1 demonstrates the effect of the initial LWA moisture on the mix water absorption. As expected, the mix water absorption decreases with increasing initial LWA moisture content. However, the total water content of the LWA still increases with increasing initial moisture. As can be seen, an interesting effect on the mix water absorption is obtained by spraying the aggregates with water immediatly before mixing.

Figure 2 shows the mix water absorption as a function of time. For the actual concrete type, significant absorption takes place during the first hour after water addition. Consequently, the calculation of the final effective mix composition for this spesific concrete should be based on density measurements after not less than 1 hour. Furthermore, if this concrete is placed and compacted immediately after mixing, the mix water absorption might cause inadequate compaction if the concrete is not revibrated after the absorption has stopped.

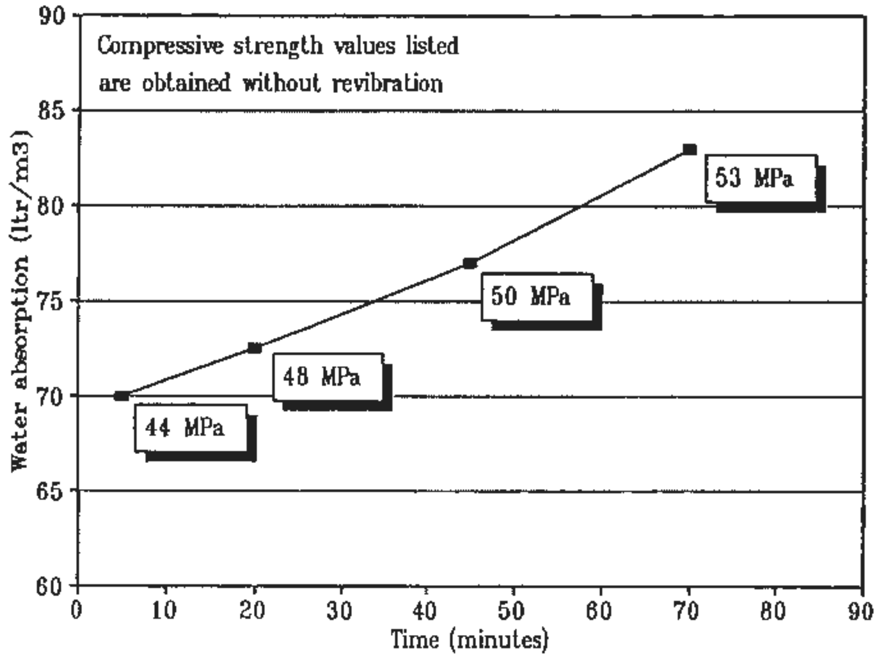

Figure 2. The mix water absorption and compressive strength as a function of time after mix water addition (example)

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