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Water vapour permeability of lightweight concrete prepared with different types of lightweight aggregates

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HIGHLIGHTS

- Pilot preparation of lightweight aggregates (LWAs) from silica sludge, fly ash and paper mud.
- Characterization of lightweight aggregates by means mercury intrusion porosimetry (MIP).
- Preparation of lightweight concrete from LWAs.
- Testing of water vapour permeability.

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ABSTRACT

The water vapour permeability of concretes or various building systems is an important parameter when defining the concept of favourable living conditions. Within the scope of the research described in this paper, the water vapour permeability of concretes prepared with different lightweight aggregates (LWA) having an open porosity was compared with that of concretes made with a selected ordinary aggregate. It was found that the coefficient of water vapour permeability μ was, in the case of all the investigated concrete prepared by lightweight aggregates and used water/cement factors, less than 35, whereas in the case of the ordinary concrete it amounted to 84. It is interesting to note that SEM investigations of the interface (transition) zone between the aggregates and the cement matrix did not indicate the occurrence of any densification which could have a negative effect on the water vapour permeability of lightweight concretes (LWAC).

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1. Introduction

According to the definitions given in the standard [6], aggregates whose maximum particle density does not exceed 2000 kg/m^3, and those whose loose bulk density does not exceed 1200 kg/m^3, can be defined as lightweight aggregates (LWA). They usually consist of natural aggregates (e.g., tuff), or else are obtained from natural resources (vermiculite, perlite, expanded clay) or from industrial waste (various types of sludge, ash, and waste glass). Lightweight aggregates can be used in concrete instead of ordinary aggregates for several reasons: (i) due to their improved thermo-insulation properties; (ii) due to their own reduced weight, thus making static loadings more favourable, and (iii) due to the internal curing of the concrete, which helps towards the achievement of higher compressive strengths [8,7,12].

The properties of concretes are affected by the properties of the aggregate and the cement matrix, and those of the interface (transition) zone between the matrix and the aggregate. On the other hand, the properties of concretes are also strongly affected by the water/cement (w/c) ratio, and the achieved degree of compaction of the material, as well as by various additives and the quantity and shape of the pores, although the shape and properties of the aggregate also have an effect on these properties.

In concretes, it is generally considered that the interface zone between the hydrated cement paste and the aggregate is the system's weakest point [1,2], which has been ascribed to the following facts:

- The interface zone has a more open morphology than the hydrated cement paste.
- It also contains large crystals of portlandite, i.e., $Ca(OH)_2$, which are oriented in such a way that, when loaded, they represent a weak point.

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Table 1
Composition of the laboratory-prepared aggregates.

Composition	AC	B0	B5
Silica sludge (%)	100	100	40
Paper mud (%)	0	0	40
Fly ash (%)	0	0	20
Processing	Granulating/firing	Firing/crushing	Firing/crushing

Table 2
Chemical composition of silica mud and fly ash and identification of mineral phases.

Components	Silica mud (in mass%)	Fly ash (in mass%)
Loss on ignition (at 950 °C)	3.5	23.2
SiO_2	81.9	28.3
Al_2O_3	9.2	10.4
Fe_2O_3	1.8	8.2
CaO	0.2	17.9
MgO	0.3	5.6
Na_2O	<0.1	0.4
K_2O	1.9	1.2
Main mineral phases	Quartz	Calcite, quartz, glass phase

- Water is apt to accumulate beneath the large grains of the aggregate, which means that additional weak points are present in the system.

In the literature some researchers e.g., [14] have stated that it is not possible, by means of lightweight aggregates with similar strengths and sizes, to achieve concretes of equal strength, even though the water/cement ratio is the same. They found that the physical and chemical properties of the aggregate are important since they have a significant effect on the interface zone between the aggregate and the matrix, which can actually extend into the aggregate itself. When water is added to the system, aggregate starts to absorb it if the latter is porous (and dry). In this way any build-up of water in the vicinity of the aggregate grains is prevented, since the water is absorbed into the grains, so that the interface zones are, as a rule and in the case of use of porous aggregate, narrower and more dense. This has an effect on the compressive strength of the concrete itself, which is increased [14,11].

In the case of concrete, also water vapour permeability is an important parameter, particularly when attempting to provide favourable living conditions. This is because, indoors, water vapour can escape only when materials are used which have an adequate permeability to water vapour (if this permeability is too low water condenses onto the walls, usually causing the development of mould – fungi). Unfortunately, there is relatively little literature from the field of the water vapour permeability of lightweight concretes, and in some cases contradictory results have been obtained. However, in principle it could be expected that the use of lightweight aggregates with open porosity could contribute to improved water vapour permeability, in particular due to the open pores of the aggregate itself.

In the case of mortars it has been found [3] that, if virgin sand is replaced with crushed bricks (which have a higher, and open type of porosity), water vapour permeability is improved. However, pore size distribution within the material also plays an important role. By performing an analysis of the permeability of various different building materials, Togkalidou et al. [13] confirmed that specific ranges of pore size distribution, corresponding to pore radii greater than 10 μm, and with values between 0.421 and 1.778 μm, contributed to better water vapour permeability of the investigated materials. However, some authors [15,9,10] found that, if the aggregate is porous, the cement matrix at the boundary of the aggregate is denser, causing a reduction in water vapour permeability.

Fig. 1. Appearance of the investigated aggregates: (a) AC – granulated, (b) B0 – crushed, and (c) B5 – crushed.

The main goal of the presented research was to verify how the water vapour permeability is affected if different types of LWAs are used in concrete since the assumption was that porous aggregate can improve water vapour permeability.. For this reason different LWACs were prepared with different LWAs having open porosity. The LWAs used in the present study were obtained in pilot production, and the concretes were prepared with either dry or wet aggregate, using different w/c ratios.

2. Experimental

2.1. Preparation of a larger quantity of LWA

The basic research material, for the pilot production, consisted of a larger quantity of LWA, which was obtained from silica sludge, and remained after sand screening in quarries.

The silica sludge contained a large amount of very fine silica sand (quartz), as well as some feldspar and clay. The particles in the sludge were smaller than 200 μm. 97% of the particles were smaller than 100 μm, whereas 48% were smaller than 20 μm, and 8% smaller than 2 μm.

Papermaking sludge and fly ash were used as additives.

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