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Permeability measurement of fresh cement paste

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ABSTRACT

Fresh cement paste permeability is a key parameter to understand the hydro-mechanical behavior of cement-based materials, i.e., rheological properties and static stability. However, its permeability measurement is not easy to assess. The porous medium is not rigid and tends to change due to hydration kinetics. Two measurement methods, with 70 mm and 20 mm initial height specimens respectively, are presented and compared in this paper. The first uses a basic cell of soil permeability measurement and consists of simultaneous consolidation and percolation tests. The second uses a displacement-controlled oedometer cell equipped with pore water pressure transducers, and consists in inducing consolidation to a given void ratio first and, consecutively, in accurately measuring the permeability. A good correlation of results is observed. A comparison with theoretical models confirms that, from one fitted parameter relative to particle characteristics, a relationship between permeability and void ratio can be established.

1. Introduction

Hydraulic conductivity is commonly called permeability coefficient ($m\,s^{-1}$) or "permeability" for short, when 20 °C water is considered as the percolating fluid. It is a key parameter to understand the hydro-mechanical behavior of fresh cement-based materials [1]. For instance, bleeding and segregation strongly depend on the paste permeability [2]. Moreover, dynamic or quasi-static stability of cement based materials controls casting, pumping [3] or forming processes like extrusion [4]. The homogeneity of the material is thus directly linked to water conductivity properties, i.e. the ability of water to move through the porous matrix made of solid particles.

Consequently, concrete permeability characterizes the ability of the concrete material to remain homogeneous during the forming process. The lower the permeability, the better the stability. This statement is valid when the material flows under its own weight or when the flow is ensured by external solicitation (pumping and extrusion). The permeability is therefore a key parameter, on which the homogeneity of the hardened material also depends. Criteria based on water permeability about extrusion ability [4] and bleeding in concrete [5] exist in the literature. Moreover, the evolution of pressure exerted by concrete on casting formwork is largely influenced by the concrete permeability [6]. During setting, permeability also should act on the rate of capillary pressure build-up and consequently on the plastic shrinkage [7].

Concrete permeability depends on the particles' nature (size distribution and specific surface area) and also on the particles' packing [8]. Specific surface influences the water adsorption forces that govern the attraction and friction forces. The particles' assembly which defines the porous solid network determines the flow path and velocity. As a consequence, water permeability theoretically depends on the particle size distribution and on packing inside the mix (i.e. Water to Cement mass ratio, W/C, in case of homogeneous cement paste).

Water conductivity measurements have been mostly developed in soil mechanics. They can be classified in two types:– Direct methods based on Darcy's law. The percolation velocity is measured under a given hydraulic head [6]. This method consists in measuring, with a constant hydraulic head, the water flow through a sample for which the mixing and shearing history is known.– Indirect methods based on the soils consolidation theory. One-dimensional compression is applied to a drained sample inside an oedometer cell (commonly called the consolidation test).

Fresh cement-based materials do not exhibit a stable porous network when they are submitted to pressure gradients or water flows. Moreover, cement hydration has a significant effect on the permeability when setting occurs, usually between the second and third hydration hours [1]. As a result, the permeability measurement of fresh cement needs specific experimental protocols.

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