PERMEABILITY PROPERTIES OF CONCRETE WITH METAKAOLIN ADDITION

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Summary

Surfacing, concrete mixture composition and curing are of great importance for the concrete surface resistance. That's the reason, why many leading experts agree on the importance of monitoring the "concrete skin" as the most loaded area affected by the external environment.

Many research works demonstrate that application of metakaolin improves properties of concrete as freeze-thaw resistance and resistance against de-icing salts with freeze-thaw cycles combination. A very important role in concrete performance in such severe environment is played by porous system and surface of hardened concrete. The paper presents an experimental program focused on the monitoring of water transport in surface layer of fair-face concrete aimed at monitoring the permeability of concrete, since concrete permeability is a property uniquely affecting durability of concrete. These methods are complemented by experimental results and other traditional tests. These findings will serve to further optimization of the structure being created, thus ensuring its better aesthetic and functional characteristics.

Keywords: permeability, porous system, metakaolin, hydraulic conductivity

1 Motivation

The origin and character of the concrete surface layer is given by the technology of production of concrete elements; during vibration compaction is going on initiation and rising of air bubbles upward. This eliminates air content in concrete, but also concentration of fine particles takes place close the walls of the formwork. Coarse aggregate – due to its geometry – cannot get its entire plane to formwork or to the corners [1]. Hence the concrete surface exhibits completely different properties compared to bulk – so called wall effect. The characteristic properties of the surface layer is low content of coarse aggregates and an increased amount of cement stone which consists of fine fractions of aggregate and cement hydration products. A very important feature is especially high content of pores in comparison with the inner layer. Such a surface layer having a thickness of 20–50 mm has a very different, usually worse properties than the surrounding material. Therefore attention is drawn to quality of concrete surface layer. Each void and crack decreases a steel covering concrete layer and thus accelerates the process of its corrosion which is associated with visual degradation of the building. Degradation processes are closely related to the quality of the surface layer and the pore system of concrete.

2 Experimental program

Permeability of porous materials is one of the principal parameter influencing their transport properties and durability. The intrinsic permeability of material K [m^2] is defined in terms of Darcy's law describing flow of a liquid through a porous material saturated by the liquid under the action of pressure gradient across the material. It is material property and thus does not depend on the kind of permeating liquid. One of possible definitions of K is given by equation (1) [1].

$$j = -K \cdot \frac{\rho_l}{\eta} \cdot \frac{\partial p}{\partial x} \qquad (1)$$

$$k = \frac{Q}{\Delta p} \cdot \frac{l}{\pi/4 \cdot d^2} \cdot \rho \cdot g \qquad (2)$$

There j is mass flux [$kg\ m^{-2}\ s^{-1}$], ρ is density of the liquid [$kg\ m^{-3}$], η is dynamic viscosity of the liquid [Pa s] and driving force is pressure gradient through the material. Intrinsic permeability is extremely dependent on properties of porous system of hardened concrete. That is one of the reasons of very different result of experimental works.

Tab. 1 *Concrete composition and properties*

Mixture		**III**	**IV**	**V**
Components		[kg/m^3]	[kg/m^3]	[kg/m^3]
Cement CEM I 42,5 R Mokrá		400	400	370
Aggregate:	sand 0–4 mm, Dobříň	930	930	930
	crushed 4–8 mm, Zbraslav	315	315	315
	crushed 8–16 mm, Zbraslav	600	600	600
Plastisizer (Sika 1035)		3	2	3
Water		180	180	180
Metakaolin		-	-	30
Bulk density [kg/m^3]		2310	2320	2325
Compressive strenght [MPa]		67,8	60,5	68,5
Hydraulic conductivity [m/s]		$1,2\cdot10^{-11}$	$1,2\cdot10^{-11}$	$1,0\cdot10^{-11}$

Hydraulic conductivity was measured by means of high pressure permeameter made by CNE Technology. The design is based on work [2]. The method is based on definition equation (2) where Q is flow rate [$m^3\ s^{-1}$], Δp is pressure difference across the sample, *l* and *d* its length and diameter and ρ is liquid density; slope of dependence of *Q* on Δp is the searched hydraulic conductivity. Equation (2) assumes the validity of Darcy's law. This method is not standardized in Europe, but there is an American standard [3]. Altogether were measured three concrete mixtures (tab. 1), with dosage of metakaolin and different amount of plasticizer.

Experiment based on Darcy’s law provides coefficient of permeability *K* valid for saturated state of material. The dependence of *K* upon volumetric moisture content *w* can be derived by help of pore size distribution of the material. Mualem [4] proposed equation (3) which uses experimentally determined pore size distribution function *f*(*r*); other input parameters are saturated moisture content w_{sat} and parameter *n*. For computing was used software HydraPor developed at Department of Material Engineering and Chemistry CTU in Prague.

$$K(w) = K\left(\frac{w}{w_{sat}}\right)^n \cdot \left(\frac{\int_{R_{min}}^{R} r\, f(r)dr}{\int_{R_{min}}^{R_{max}} r\, f(r)dr}\right)^2 \qquad (3)$$

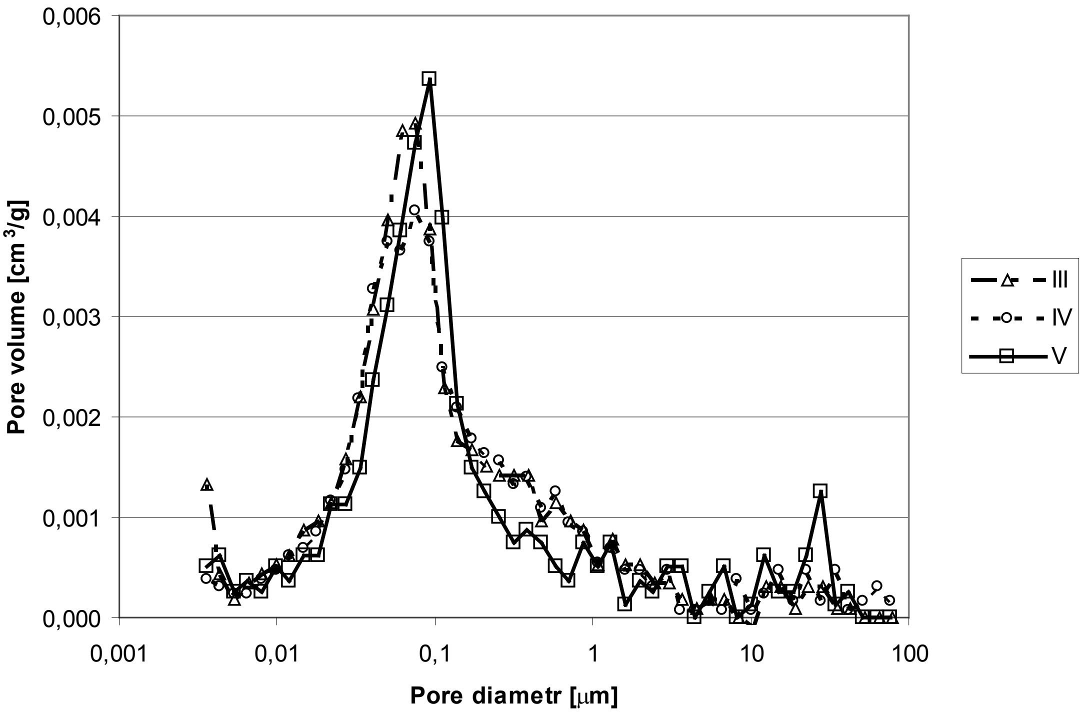

Fig. 1 *Pore distribution*

Pore size distribution was determined by means of mercury intrusion porosimetry (MIP). The method is based on intrusion of mercury – non wetting liquid – to pores of studied sample. The penetrated pore’s diameter is inversely proportional to applied pressure (Washburn equation). The applied pressure is gradually increasing during the experiment and thus mercury penetrates narrower pores. The result of experiment is dependence of pore volume (it corresponds to measurable volume of intruded mercury) upon pore diameter (corresponds to applied pressure). The experiment was carried out by means of Pascal 140 and 440 devices (Thermo).

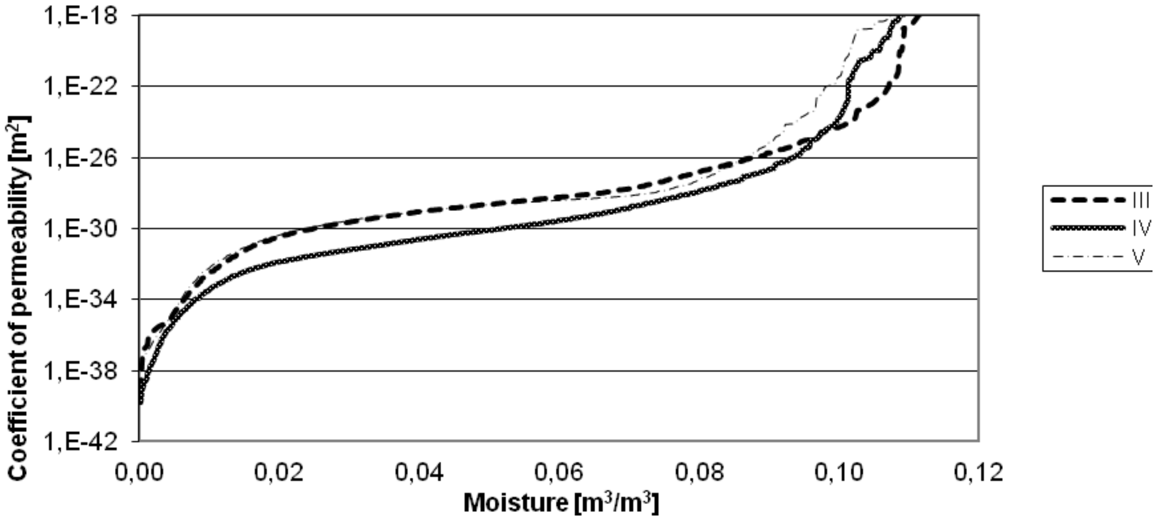

Fig. 2 *Coefficient of permeability as function of moisture content*

3 Conclusion

Durability depends not only on the quality of the surface layer, but also on the nature of the pore system that is truly defining parameter because it affects the rate at which aggressive substances, gaseous or liquid, penetrate from the external environment into the internal structure of concrete, and thus the rate of degradation of the material and its durability. Very important is the limitation of water and moisture transport of having a role in reinforcement protecting against corrosion. Results of these tests will become the basis for a correlation dependence permeability of concrete and concrete methodologies for evaluation in terms of its durability.

Acknowledgement

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