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Increasing of the Durability of Concrete Cover

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Abstract. The paper introduces an experimental program focused on the monitoring of water transport in surface layer of concrete aimed at monitoring the permeability of concrete, since concrete permeability is a property uniquely affecting durability of concrete. Introduced 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.

Introduction

In connection with the introduction of the new standard system came into issues of concrete durability on importance. Action of aggressive media concentrated in the external environment is to develop a wide range of corrosion mechanisms. Most buildings are protected from the effects of adverse conditions by other types of structures. In case of the fair-face concrete, however, this protective layer is formed by the material itself. Due to the fact that concrete degradation processes are going on a long-term, and aggressive substances act at low concentrations, it is very difficult to describe such effects and to quantify the resulting degradation phenomenon under test in the laboratory. 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. Contribution is focused on the study of permeability of the concrete surface modified by application of Controlled Permeability Formwork (CPF).

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, 2]

$$j = -K \cdot \frac{\rho_l}{\eta} \cdot \frac{\partial p}{\partial x} \ , \tag{1}$$

where j is mass flux [kg·m^{-2}·s^{-1}], ρ_l 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. Considerable deficiency of EN standard system is the absence of a test which would enable to quantify rate of water penetration to concrete by coefficient of permeability [m^2]. Usually is problem of concrete permeability solved providing water penetration test (WPT) according EN 12390-8, but result of mentioned test is only the depth [mm] of visible water penetration. According WPT has water pressure 0.5 MPa for 72 hours. For mentioned experimental program were designed four concrete mixtures presenting common used composition and strength of concrete in Czech Republic, showed in Tables 1 and 2. In performed experimental program was WPT performed together with gravimetric measuring of penetrating water. From obtained data was provided qualified estimation of coefficient of permeability for different concrete mixtures and surface modification.

Table 1. Composition of studied concrete mixtures.

Concrete mixture		**I**	**II**	**III**	**IV**
Components		[kg/m^3]	[kg/m^3]	[kg/m^3]	[kg/m^3]
Cement CEM I 42,5 R Mokrá		350	350	400	400
Aggregates	sand 0-4 mm, Dobříň	785	830	930	930
	crushed 4-8 mm, Zbraslav	350	350	315	315
	crushed 8-16 mm, Zbraslav	650	580	600	600
Plasticizer (Sika 1035)		0	0	3	2
water		186	208	180	180

Table 2. Basic properties of studied concrete mixtures.

Concrete mixture	**I**	**II**	**III**	**IV**
Bulk density [kg/m^3]	2325	2330	2310	2320
Compressive strength [MPa]	46.7	43.8	67.8	60.5

Controlled Permeability Formwork (CPF) is two-layered liner with a permeable side allowing water and air to pass through and a filter side designed with a pore size slightly smaller than fine particles of concrete. The main function of CPF is to drain surplus water and air from the surface of fresh concrete. Increasing of permeable properties of concrete cover is caused by reducing of water/cement ratio. Results of WPT are showed in Table 3.

Table 3. Results of water penetration test.

Mixture	**Depth of penetration [mm]**		**Amount of penetrated water after 72 hours [g/m^2]**	
	Reference	**CPF**	**Reference**	**CPF**
I	100	35	31682.0	4073.4
II	80	24	52841.1	7920.5
III	38	24	10183.5	5770.7
IV	48	3	13464.9	2489.3

Evolution of the amount of penetrating pressure water into the concrete is showed in Figure 1 and Figure 2. There is evident effect of used surface treatment. Thanks using of CPF was cumulative amount of penetrated water on the level of about 15 %, but efficiency is different for each studied mixture. It is caused by different composition of produced mixtures.

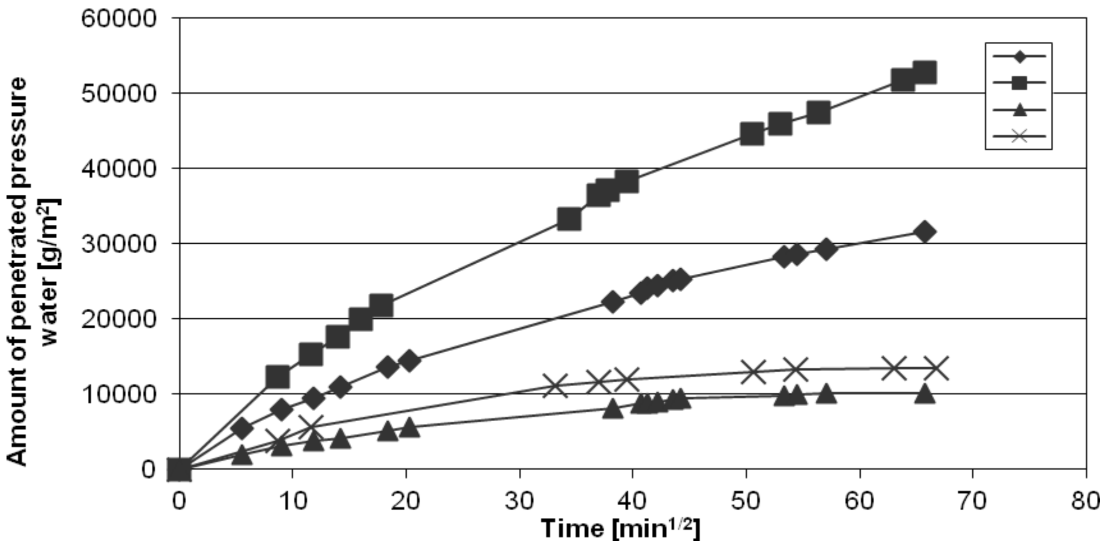

Fig. 1. Amount of penetrated water during WPT – without surface treatment.

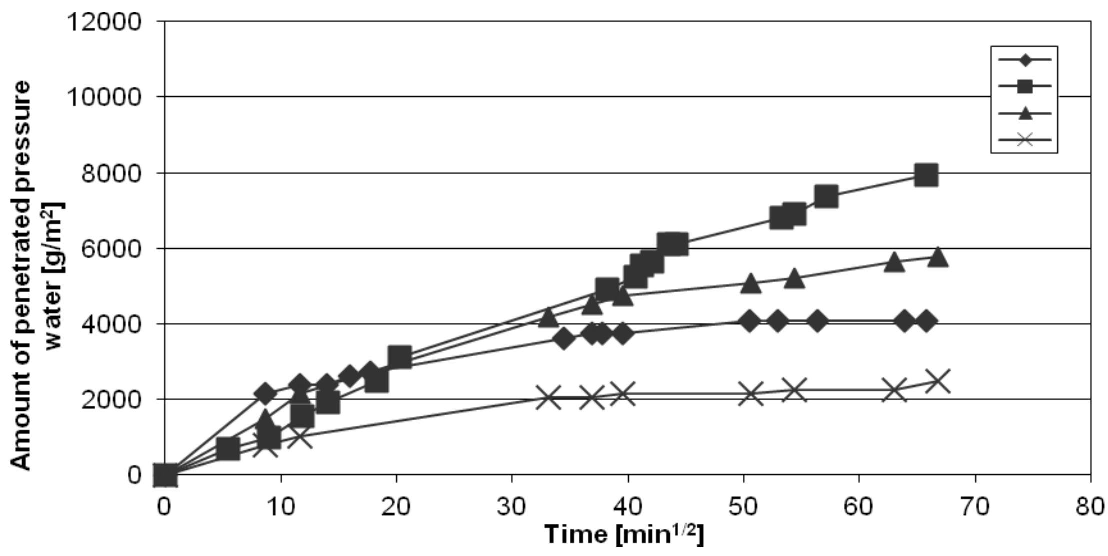

Fig. 2. Amount of penetrated water during WPT – with use CPF.

Due to high value of water/cement ratio and portion of fine components were mixture I and II the most permeable, that is the reason why application of CPF was very efficient. In case of mixtures III and IV, with low primary permeability, was impact of CPD reduced, probably by dose of plasticizer. Well dispersed fine particles could seal off the filtering layer of the forming system. Coefficient of intrinsic permeability was estimated according Darcy's law (1) from the initial penetration of pressure water, where is possible to suppose linear flow. Final values of permeability coefficient are shown in Table 4.

Table 4. Estimation of coefficient of intrinsic permeability.

Mixture	**Surface treatment**	**k_i [m^2]**
I	Reference	$1.441 \cdot 10^{-15}$
	CPF	$5.460 \cdot 10^{-17}$
II	Reference	$1.315 \cdot 10^{-15}$
	CPF	$1.082 \cdot 10^{-16}$
III	Reference	$5.705 \cdot 10^{-16}$
	CPF	$3.521 \cdot 10^{-17}$
IV	Reference	$8.452 \cdot 10^{-16}$
	CPF	$2.971 \cdot 10^{-17}$

Conclusions

Very important is the limitation of water and moisture transport of having a role in reinforcement protecting against corrosion. At this point it should be noted that the in construction practice and research, the term of permeability is used quite freely (for different tests), it is always necessary to present the results along with the method and conditions of the experiment [3]. It is obvious that a material will have a dramatically different permeability for air, for water or "permeability" of the chloride ions, reported in the Coulombs [4].

Measured data indicate that the composition of concrete mixtures significantly affects the properties of a surface layer of concrete, while the 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.

Due to the fact that concrete degradation processes are going on a long-term, and aggressive substances act at low concentrations, it is very difficult to describe such effects and to quantify the resulting degradation phenomenon under test in the laboratory. In the case of porous building materials is intrinsic permeability one of the parameters that affect their behavior in structures; depend on it water resistance and indirectly resistance to action of frost, salts and other degradation processes, that is durability.

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