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HYGRIC PROPERTIES OF HPC EXPOSED TO SALT ATTACK

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1. Introduction

The progressive building materials development improves their quality and utility value. In order to achieve better material properties, besides the new technologies also specific admixtures are employed. The accurate admixtures dosage and technological conditions observation can improve the material parameters like strength and durability. Most frequently, the mineral admixtures, for example pozzolana, fly ash or flue cinder, are used in concrete production. Fine siliceous materials usually called silica fume belong to relatively newly applied materials improving concrete quality.

Despite the gradual shift in the HPC design and application philosophy towards a generally recognized necessity to measure a wider scale of HPC parameters the mechanical properties still remain the far most frequent parameters investigated in the research work being done on HPC. Water and water vapor transport and storage properties of HPC were not yet in the center of interest of most researchers until now although they possess a very high predicative potential concerning the HPC quality.

In this paper, basic hygric properties of two types of high performance concrete are measured after salt attack being induced by immersion in 3-M NH_4NO_3 solution for three months and compared to the properties in reference state.

2. Experimental methods

Basic physical parameters

As fundamental physical material characteristics, bulk density ρ_b [kgm^{-3}], porosity [Vol.-%] and matrix density ρ_m [kgm^{-3}] were determined. They were obtained using the gravimetric method and the vacuum saturation method [1].

Water vapor transport properties

The wet cup method and the dry cup method were employed in the measurements of water vapor transport parameters [1]. The water vapor diffusion coefficient D [m^{2}s^{-1}] and water vapor diffusion resistance factor μ [-] were determined.

Water transport properties

The water sorptivity A [$kgm^{-2}s^{-1/2}$] and apparent moisture diffusivity κ [m^2s^{-1}] were measured using a water suction experiment [2].

3. Materials

Two different types of concrete, namely the high performance concrete C90/105 containing microsilica and the same material C60/75 without microsilica, were studied. Table 1 presents the composition of the studied cement mixtures. The first part of specimens was analyzed in reference state, the second after being immersed in 3-M NH_4NO_3 solution for three months.

Table 1 Composition of HPC mixtures
Tabulka 1 Složení cementových záměsí

HPC	Composition of 1 m^3 in kg							
	CEM I 52.5 R	*SiO_2 suspension	Aggregates 0-4 mm	Aggregates 4-8 mm	Aggregates 8-16 mm	**Woerment FM 794	***Lentan VZ 33	w/c
BI	480.0	72.0	664.0	207.0	995.0	7.74	2.58	0.36
BII	470.0	-	668.0	209.0	1001.0	5.17	2.35	0.33

* SiO_2 suspension – water suspension consisting of 88-95% of SiO_2 and small amounts of calcium oxide, magnesium oxide and nitrogen oxide

** FM 794 – plasticizer on the basis of polycarboxylateether

*** Lentan VZ 33 – hydration retarder on the saccharose basis

4. Results and Discussion

The results of basic parameters measurements are presented in Table 2. The open porosity of both studied HPC decreased by about 15% after being exposed to NH_4NO_3 solution but the matrix density decreased as well – by approximately 2%. This could be attributed to a chemical reaction between the cement matrix and NH_4NO_3 [3] which filled a part of the porous space by its products. The bulk density of both materials increased only very slightly which was clearly the effect of bound salts.

Table 2 Basic material parameters
Tabulka 2 Základní materiálové vlastnosti

HPC	Reference states			Exposed to NH_4NO_3		
	ρ_b	ρ_{mat}	ψ_o	ρ_b	ρ_{mat}	ψ_o
	[$kg\ m^{-3}$]		[%]	[$kg\ m^{-3}$]		[%]
BI	2423	2760	12.23	2453	2697	10.53
BII	2388	2647	10.40	2390	2585	8.91

The results of measurements of water and water vapour transport parameters of the studied hardened cement mixtures are presented in Tables 3 and 4.

Table 3 Water vapour transport properties
Tabulka 3 Transportní parametry vodní páry

HPC	Reference states				Exposed to NH_4NO_3			
	D [m^2s^{-1}]		μ [-]		D [m^2s^{-1}]		μ [-]	
	97-25%	5-97%	97-25%	5-97%	97-25%	5-97%	97-25%	5-97%
BI	1.36E-06	1.14E-6	16.94	20.11	1.27E-06	1.01E-06	18.05	22.69
BII	1.48E-06	1.21E-6	15.49	18.95	1.33E-06	1.12E-06	17.32	20.60

The water vapour diffusion resistance factor increased for both materials in both wet cup and dry cup arrangements by about 10% due to the NH_4NO_3 solution exposure. This is in basic accordance with the decrease of open porosity in Table 2.

Table 4 Water transport properties
Tabulka 4 Transportní parametry kapalné vlhkosti

HPC	Reference states		Exposed to NH_4NO_3	
	A [kg $m^{-2}s^{-1/2}$]	κ [m^2s^{-1}]	A [kg $m^{-2}s^{-1/2}$]	κ [m^2s^{-1}]
BI	0.0078	4.09E-09	0.005	2.09E-09
BII	0.018	2.93E-08	0.0039	1.10E-09

The water transport parameters were after immersion in NH_4NO_3 solution reduced as well. Water absorption coefficient decreased by about one third in the case of BI and even four times for BII. Moisture diffusivity decreased accordingly. The effect of filling the pores by the products of chemical reaction of NH_4NO_3 with the cement matrix was thus more pronounced for liquid water transport than for water vapor transport. This is apparently a consequence of reducing the preference paths for water transport by filling larger pores.

5. Conclusions

Experimental studies presented in this paper showed that water and water vapour transport properties of studied HPC were reduced after the specimens were exposed to 3-M NH_4NO_3 solution for three months. This effect was observed for HPC both with and without microsilica addition. The decrease of water and water vapor transport capability was in a good agreement with the decrease of open porosity and was an apparent consequence of chemical reaction of NH_4NO_3 with the cement matrix. According to the previous studies [3], in further phases of ammonia salts action on cement matrix the pores should be fully filled by reaction products and the material should be damaged due to the increase of internal pressures. This will be subject of further investigations when NH_4NO_3 will be allowed to act on HPC specimens for a longer time.

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References

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VLHKOSTNÍ PARAMETRY VYSOKOHODNOTNÉHO BETONU PO VYSTAVENÍ PŮSOBENÍ SOLÍ

Anotace

V článku jsou studovány základní vlhkostní parametry dvou záměsí vysokohodnotných betonů v referenčním stavu a po vystavení působení 3-M roztoku NH_4NO_3 po dobu tří měsíců. Výsledky experimentů ukazují, že transportní parametry vody i vodní páry jsou u obou studovaných materiálů v důsledku působení NH_4NO_3 redukovány, což je v dobrém souladu se snížením pórovitosti. Pozorované změny vlhkostních parametrů jsou pravděpodobně způsobeny chemickou reakcí NH_4NO_3 s cementovou matricí, jejíž produkty způsobují částečné zaplnění pórového prostoru.