CONCRETE PERMEABILITY

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Abstract

Permeability is one of the main factors that affects resulting durability of concrete i.e. immunity against incidence of outer forces. Assessment of the durability is nowadays much discussed characteristic above all in relation to permanent sustainable development of concrete construction. The paper deals with problems of incidental permeability of concrete from the point of view that the penetration waters porous characterize structure concrete - cement stone. It's defined above all by water-tightness, capillarity attraction and absorbability of concrete, whereas all these characteristics depend upon porosity of cement stone.

Keywords: concrete, permeability, cement stone, absorbability, capillarity, airiness

1 Concrete properties

Concrete properties could be divided four groups after common signs:

- Mechanical characteristics i.e. tensile strength, transversal compressive strength and shear strength
- Deformation characteristic i.e. properties related with change of capacity, action of the forces (Young's modulus, creep of concrete) or action of the inner forces (shrink)
- Durability of concrete i.e. resistance to action of the loads forces, fields and chemical materials (fire resistance, frost resistance, chemical resistance, grind ability, resistance to corrosion concrete and steels).
- Permeability of concrete whose describes motion of the energy flow (water-tightness, capillarity, absorbability, airiness, heat and electric conductivity).

While most of the interest in concrete permeability dates back to initial construction of hydroelectric structures in the 1930s, there is a renewed awareness of the role that permeability plays in the ultimate durability of concrete structures.

2 Permeability of cement stone

The permeability of concrete is affected also by the properties of cement. Porosity of structural cement stone enables penetration of the fluent and the liquid materials and at the same time interference heat transit. Individual characteristics are defined physically (diffusion of water vapours, heat conductivity, electric conductivity) or technologically (hygroscopicity, absorbability, capillarity, water-tightness, airiness).

2.1 Hygroscopicity

Hygroscopicity is the capacity to absorb on self inside surface water vapours from atmosphere (in peruses). Cement stone is hydrophilic material which absorbs water. Water absorption depends on relative humidity and distribution of capillary pores (inside surface area). Thickness of absorbed water layer is:

$$\delta_V = \frac{0{,}3656}{\sqrt{-ln\,\varphi}} \qquad (1)$$

Value of thickness layer is from 0,3 to 1,7nm and φ is relative humidity. Continuation of cement hydration enables increase of humidity absorption so that strength of cement stone grows up.

2.2 Absorbability

Absorbability is capacity to fill open pores of cement stone with water. It's due to hydrostatistic pressure and capillary forces. Absorbability units are percents of materials weight. Absorbability can be restricted by air pressing in impassable capillaries. (e.g. impassable capillary with radius 1μm have overpressure 230kPa). Absorbability in vacuum per 24 hours is three time higher than absorbability in normal compression.

2.3 Capillarity

Capillarity is the difference of the height between water level in capillary and water level in which specimen is placed. After a certain time the balance of capillarity forces and gravity will be stabilize. Height of capillarity action is:

$$h = \frac{2 \cdot \sigma_P \cdot cos\,\psi}{r \cdot \rho_V \cdot g} = konst.\left(\frac{1}{r}\right) \qquad (2)$$

where: σ_P is surface tension, ψ is wetting angle, r is capillary radius, σ_V is water density and g is gravity

2.4 Water-tightness

Water-tightness is reversible value of permeability of porous mediums. Water-transmission is smaller than ratio of water and air viscosity. On the inside capillaries surface is water absorbed, through profile of capillaries tapers. The laminar flow in capillaries is interrupted. Electrostatic forces of polar liquid act. Water quantity extruded trough capillary system is determined by Hagen-Poiseuill's principle:

$$V_V = \frac{D_v \cdot S \cdot \Delta p}{\eta \cdot l}; \quad D_v = \frac{r_{ef} \cdot P_K}{8} \qquad (3)$$

where: D_V is specific permeability ratio, r_{ef} is radius of effective pores, P_K is capillary porous, S is surface, Δp is capillary radius, η is water viscosity and l is pores longitude

Speed of the water penetration over capillary system of cement stone is got at the nomogram on the Fig. 1.

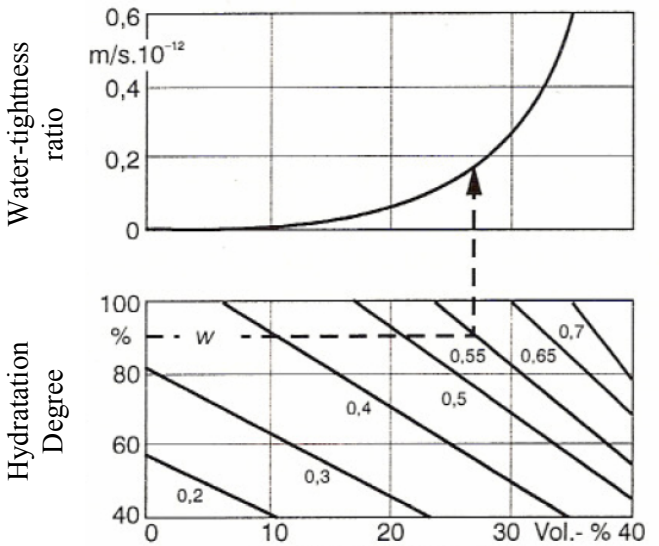


Fig. 1 nomogram for water-tightness of cement stone

2.5 Airiness

Airiness is infiltration over empty pores of cement stone. Air infiltration pores which size is above 2.10^{-5} – 10.10^{-5}m or cracks which depth is greater than 10^{-5}m. Airiness get down with age of cement stone.

2.6 Diffusion of water vapour

Water vapour diffusion is characterised by diffusion of water vapour ratio δ [s]. For cement stone δ has value $0{,}010.10^{-9}$s. Quantity of water vapour depends on difference of partial pressure between two surfaces and field of temperature inside material. When temperature gets down than pressure of water vapour will be saturated and water vapour will condensate in porous mediums. By this condensation gets up material's humidity and at the same time gets up heat conductivity of cement stone.

2.7 Heat conductivity

Heat conductivity λ [$W.m^{-1}.K^{-1}$] depends on material's homogeneity, crystal structure of solid phase and character of porosity. For engineering calculations is cement stone heat conductivity $\lambda_{CK} = 0{,}815$ $W.m^{-1}.K^{-1}$ (by specific gravity 1950 $kg.m^{-3}$).

2.8 Electric conductivity

Cement stone electric conductivity is greater than stone electric conductivity. Dried-up cement stone electric resistance (reverse value to electric conductivity) is about $10^{7}\Omega.m$. Electric resistance gets down hardly when humidity gets up and particularly when in pores of cement stone gets up sour concentration.

3 Concrete permeability

Permeability and other decisive ultimate compressive strength are key factors affecting durability. Low strength and high permeability decrease durability. Concrete permeability is defined by properties which characterize water penetration over porous structure of cement stone (absorbability, capillarity, water-tightness), air penetration (airiness, diffusion of water vapour), heat conductivity and electric conductivity. All these properties depend on at porosity of cement stone given above.

3.1 Concrete water-tightness

Water-tightness is one of the major properties of hardened concrete. Open capillary greater than 10^{-7}m are dominant for concrete water-tightness. Penetration trough micro-pores is impossible. Water-tightness depends on displacement and distribution of macro-pores and capillaries in a cement stone. Water-tightness is possible defined by permeability ratio:

$$k_p = \frac{V_v}{3600 \cdot S \cdot t \cdot \Delta p} \quad \left[m \cdot s^{-1}\right] \qquad (4)$$

where: V_V is water displacement that pass through surface S during time t with pressure gradient $\Delta p = 10^5$Pa

At the Fig.2 is correlative affinity. Quantity of macro-pores in concrete depends on water ratio. Over time capillary are filling-up by cinder minerals and water-tightness get up (see Tab.1).

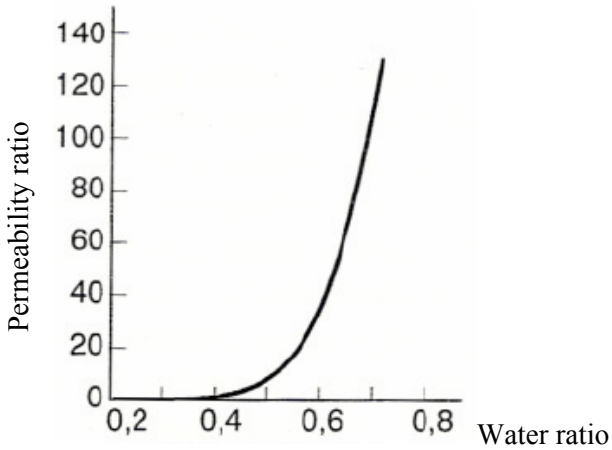
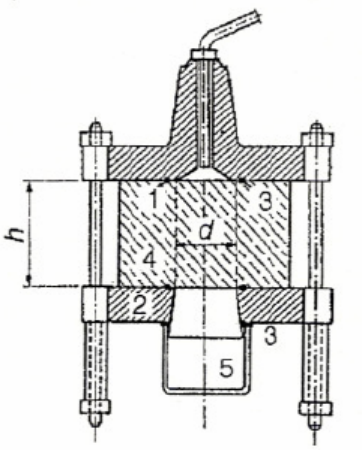


Fig. 2 dependence permeability ratio on water ratio

Age of concrete	Permeability ratio, k_p [m.s^{-1}]
Wet	2.10^{-6}
7 days	10^{-11}
28 days	10^{-12}

Tab. 1 dependence permeability ration on age of concrete

In Czech Republic is concrete water-tightness test in agreement wit standard ISO 7031 Hardened concrete – assessment depth Stanovení hloubky průsaku tlakovou vodou. Test is made with three prism specimens with length of edge 150mm, 200mm, 300mm or bores. Ratio of height to length must by greater than or equal to 0,5. Recommended age of concrete is 28 days.



1 – upper board
2 – bottom board
3 – rubber packing
4 – testing specimen
5 – case for drips
d = 75mm
h ≥ 100mm

Fig. 3 measuring installation for assessment water-tightness

3.2 Concrete humidity characteristics

Concrete humidity's characteristic are: balance humidity, absorbability, capillarity, absorption characteristic (wettability and drying ability).

These characteristics are tested by standards:
ČSN 73 1316 Stanovení vlhkosti, nasákavosti a vzlínavosti betonu
ČSN 73 1327 Stanovení sorpčních vlastností betonu

These characteristics depend on porous cement stone. Primarily depend on macro-capillary proportion and cement stone quantity in concrete. Absorbability and capillarity get down when water ration get down.

3.3 Air permeability

Air quantity q_m [kg.m^{-2}.s^{-1}] is defined by:

$$q_m = \varepsilon_m \frac{\Delta p}{d} \qquad (5)$$

where: ε_m is specific air permeability ratio, Δp is capillary radius and d is thickness of concrete deck

Specific air permeability ratio is materials constant which depends on open and clear pores of material. Pores and cracks with size over 10^{-7}m are aerating. Airiness permeability values are in Tab. 2. Permeability is tested by oxygen penetration. The test results give capillary porosity of concrete. Permeability get down when are add aeration aggregates.

Concrete	Density [kg.m^{-3}]	Specific air permeability ε_m [s]	Diffusion of water vapour δ [s]	Heat conductivity λ [W.m^{-1}.K^{-1}]
Plain c.	2100-2300	(1,2-1,4).10^{-9}	0,013.10^{-9}	1,28-1,54
Reinforced c.	2300-2500	(1,2-1,4).10^{-9}	0,008.10^{-9}	1,63-1,72
Keramzite c.	700-1700	(1,5-3,6).10^{-4}	(0,013-0,025).10^{-9}	0,3-1,2
Light c.	to 1000 1000-2000			0,49 0,62-1,60

Tab. 2 materials parameters of concrete

4 Conclusions

Permeability refers to the amount of water migration through concrete when the water is under pressure or to the ability of concrete to resist penetration by water or other substances. Permeability is an important property that governs many aspects of the durability of concrete structures. Decreased permeability improves concrete's resistance to freezing and thawing, resaturation, sulphate, and chloride-ion penetration, and other chemical attack. The permeability of the paste is particularly important because the paste envelops all constituents in the concrete. Submitted paper is dedicated to the problem of permeability of cement stone and concrete. The contribution deals with basic information about the properties which define the permeability.

Acknowledgements

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