FIBRE CONCRETE AND ITS AIR PERMEABILITY

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Abstract:

A quality of a covercrete (covercrete = cover concrete) up to a depth of 20-50 mm practically decides about the durability of concrete of a structure. The covercrete prevents accessing of acid substances from the atmosphere to steel reinforcement. For evaluation of a state of the covercrete from the durability viewpoint is possible to use a test either of the air or water permeability. Permeability of a thin covercrete depends on its porous structure that forms itself at a process of hydration of cement grains in concrete. The permeability is also influenced by cracks and by others discontinuities in monitored layer which form themselves as early as at setting and in the beginning of hardening due to plastic shrinkage and imperfect compacting of concrete. In this contribution are described some results of measurement of air permeability with a TPT (Torrent Permeability Tester) instrument of selected concretes with different type of fibres and comparative concretes without fibres.

Keywords: fibre concrete, permeability, pore system, cover layer, concrete durability (

1 Introduction

The problem of durability of concrete and especially of reinforced concrete is one of the most frequent topics presented in the technical papers nowadays. In the last two decades, many special concretes of excellent properties, especially with compressive and tensile strengths), was successfully designed and verified. To manufacture concrete of the compressive strength 100 MPa and higher is not the problem. The questions of its durability rather decrease a rate of expectation of future development of its characteristics. The problem of durability of these new concretes which have a little in common with conventional concrete (cement and small aggregates) becomes a centre of the interests of many researching institutes worldwide. The covercrete of a thickness 20 – 50 mm should prevent from environmental agents acting and their penetration to the steel reinforcement and from feared corrosion starting. The characteristic of the covercrete should preserve reinforcement for as long time as possible, in fact for the time corresponding to the serviceability of a structure. The covercrete is formed by a matrix and aggregates. Since the aggregates are mostly impermeable (or very little permeable), only cement matrix is permeable. The cement matrix originates by hydration of clinker minerals in cement agent and there itself changes on a system of the hydrated minerals. The character of this change is both chemical and mineralogy. Besides these minerals a calcium hydroxide also originates. At the formation of a new structure of cement agent, a certain amount of pores of different sizes originate. From the viewpoint of durability are important the pores which

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diameters are 10-7 m (micro-pores) and 10-5 m and greater (macro-pores). The permeability of the porous structure is considered to be a property that is competent to assess an actual state of monitored layer in the best way. Easily for 30 years many institutions have been trying to find a testing method of measuring permeability with the high or low success. The permeability is measured for the liquids and gasses, mostly for the water and air. From the first methods Figga [1] from the year 1971 up to the real permeability-meters of a period around the year 2000, many methods with oxygen and carbon dioxide were examined but none was so conclusive to become an official method of RILEM. Closest to this method are the methods Cembureau and TPT (Torrent Permeability Tester). The institution (a laboratory) of the authors´ is equipped with the TPT device and the permeability has been measured on several thousand samples of concretes.

2 Experimental

2.1 Torrent Permeability Tester

The main features of the so-called “Torrent Permeability Tester” method are a two-chamber vacuum cell and a regulator that balances the pressure in the inner (measuring) chamber and in the outer (guard-ring) chamber. The operation is as follows: the cell is placed on the concrete surface and a vacuum is produced with the pump. Due to the external atmospheric pressure and the rubber rings, the cell is pressed against the surface and thus both chambers are sealed. After l minute the blue stop-cock is closed and the rate at which the pressure raises in the inner chamber is recorded; this rate is related to the permeability of the underlying concrete. The design of the apparatus ensures a unidirectional air flow into the inner chamber, which makes it possible to calculate a coefficient of permeability (k_T [m^2]), on the basis of a theoretical model (Fig. 1). The method is fast (total duration between 1.5 and 12 minutes for high and low permeability concrete, respectively), totally non-destructive and therefore suitable for both laboratory and site applications. The importance of the moisture content of the concrete on the measured gas permeability is well known; hence the need to find measures to counteract it. At each measurements of permeability the moisture of a covercrete is measured by a capacitive hydrometer. A value of the weight moisture is assigned to each kT value. For dry concrete the quality of the covercrete can directly be identified by entering the measured and indicated k_T value of the Torrent Permeability tester into Table 1.

Tab. l Classification of the quality of the covercrete according to k_T

Classification of the quality of the		k_T measured at 28 days [k_T . 10^{-16} /m^2]
1	very good	$k_T < 0.01$
2	good	$0.01 < k_T < 0.1$
3	normal	$0.1 < k_T < 1.0$
4	bad	$1.0 < k_T < 10$
5	very bad	$k_T > 10$

The influence of the moisture on permeability changes itself with the age of concrete (by its drying and the water consumption for subsequent hydration of cement grains in concrete). At the recording of k_T the actual data of the weight moisture in % is added.

Fig. 1 Torrent Permeability Tester

2.2 Application of various types of fibres into concrete

Many publications have dealt with the influence either of steel or polymeric fibres addition on the characteristics of tested concrete. Tensile strengths improved themselves mostly, sometimes also compressive strengths, especially of the concretes with the steel fibres.

2.2.1 Fine polymeric fibres

Fine fibres are applied so as to restrict the development of small cracks and micro-failure caused both by plastic shrinkage and settlement in the phase of setting and at the beginning of hardening (between 2-6 hours after concrete imbedding into a formwork). They improve a capability of young concrete to absorb the strain originating at the formation of neoplasm at the process of cement hydration. The fibres reduce amounts and widths of the cracks and contribute to the restriction of cracks development caused by autogenous shrinkage in the later phase of cement hydration in concrete. The cracks, caused by insufficient curing with the water, often developed in the areas of the cracks caused by plastic shrinkage of concrete. By restriction of these small cracks an onset of others types of the cracks is reduced. The modulus of elasticity and strength of the fine fibres are small, nevertheless they are capable to a certain extent of the tensile or shear strengths to resist to their effects. The acting of the fibres do not only consist in the reduced development of the cracks, they also improve the resistance of concretes against freeze, blast and abrasion and at the same time they decrease a depth of the water and chemical substances penetration into a structure of covercrete.

For experimental test were used commercially produced polypropylene fibres Cemfiber of a length 12 mm and 18 μm in diameter in two dosing of 0.6 and 0.9 kg in 1 m3 of fresh concrete and polypropylene fibres Fibruco of the similar characteristics and the same dosing. The fibres were applied into 1 m3 of fresh concrete C 25/30 with a dose of cement CEM I 42,5 R of amount 350 kg; a ratio of the fine and coarse aggregates was 3:2, water ratio $\omega = 0{,}48$ and a plasticizer Sika V3 in amount of 3.5 l in 1 m3 of fresh concrete.

The compressive strengths of referential concrete (R) without fibres were 29 MPa after 28 days of maturing, of the fibreconcretes they were almost the same – close below 29 MPa. The tensile bending strengths of the referential concrete were 6.1 MPa, of the concretes with Cemfiber (marked: Ce 0.6 and Ce 0.9) were 6.6 and 7.1 MPa and the concretes with fibres Fibruco (marked: Fi 0.6 and Fi 0.9) were 7.4 and 7,8 MPa – i.e. about 10 – 20 % higher. Since the moisture of the tested concretes have a significant role for the determination of permeability factor k_T . 10-16 [m^2], the moisture was measured with a capacitive hydrometer and via a calibration relation it was transformed on a weight moisture ω [%]. With the decreasing moisture of concrete (e.g. by gradual drying up in a laboratory at the temperature (20+3) o C and the relative humidity (40+15) % the value k_T increases because of the reduction of the water and water vapour in the porous system. A graph in Fig. 2 presents a course of the increase of kT value in dependence on the age of the tested samples. From the course of the lines is evident the influence of the samples drying up and especially the fact that from the age of 7 days of the referential concrete without fibres the value k_T is higher than the one of all fibreconcretes. Similarly, from the graph in Fig. 3 can be seen analogous trend, when expressing the kT dependency on the weight moisture. Again, the fibreconcretes show lower permeability in comparison to the referential concrete, which is clear evident at the testing of the dried-up samples of concretes (ω = 0 %).

Discussion of the results: the results of relatively extensive measurement of the permeability unambiguously proved that by addition of both types of the fine polymeric fibres into concrete in two recommended volumes, the air permeability was significantly lower (more than 50 %) than the one of the referential concrete. I can be assumed that in the initial phase of the setting and hardening of concrete the fibres transferred tensile stresses originated in a structure of concrete. Probably, an extent of the micro-failures development was reduced in the introduced period of history of the tested concretes.

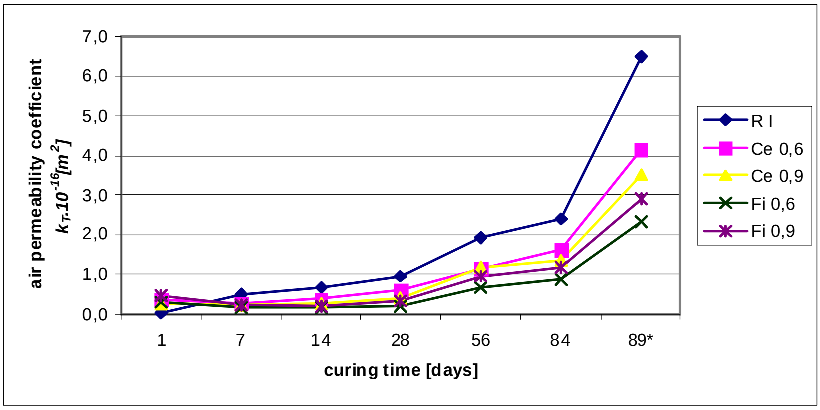

Fig. 2 Dependance the air permeability coefficients on curing time

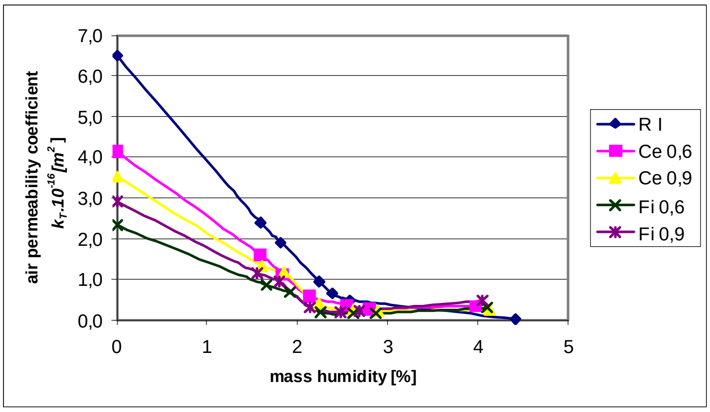

Fig. 3 Dependance the air permeability coefficients on curing time

2.2.2 Structural polymeric fibres

New high strength polymeric fibres of a labelling FF 54 (Forta Ferro), EC 38 and EC 19 (Forta Econo Net) came to our market before several years. The numbers on the label give a length in mm. The fibres FF 54 are specified for structural concretes in which they improve significantly their strengths. The institution of the authors´ has used these fibres into the lightweight structural concretes (LWSC) made from Liapor for more than 4 years. These fibres help to correct a very unpleasant property of these concretes – their brittleness. High brittleness of the LWSC, in comparison to conventional concrete, is given by different mechanism of deformations and failures [3] [4]. They can also positive influence the concrete durability (in ordinary amount 9 kg/m^3 of fresh concrete) [5]. The other two types of fibres are specified especially for shrinkage reduction. After the experience with the favourable effects of fine PE fibres on the permeability of common concrete, the verification of the high strength fibres effects on the permeability was carried out. At the primary verification of the application of FF 54 in amount 9 kg/m^3, EC 38 and EC fibres in amount 0.9 kg/m^3 of fresh concrete were gained very interesting results checking the presumption that also this type of the fibres would influence the permeability.

Referential concrete (marked REF) was composed of: Liapor CZ of a fraction 4/8 mm in volume 0.44 m^3 in 1 m^3 of fresh concrete, cement CEM I 42.5/R of amount 400 kg /m^3 in fresh concrete, sand 0/4 mm of amount 580 kg/m^3 in fresh concrete, fly ash Třinec - 50 kg/m^3 in fresh concrete, superplasticizer Sika – 5 l/m^3 in fresh concrete and the water - 206 l/m^3 in fresh concrete. The fibres were added to the identical concrete. The labelling of the samples of concretes corresponds to the labelling of the fibres.

An average compressive strength of concrete determined on the cubes 150/150/150 mm of the age 33 days at storing of the samples in humid environment was 36 MPa at the average volume weight 1650 kg/m^3 of fresh concrete. The influence of the fibres addition on the permeability of concrete described by the air permeability factor k_T (TPT) is shown in Fig. 4.

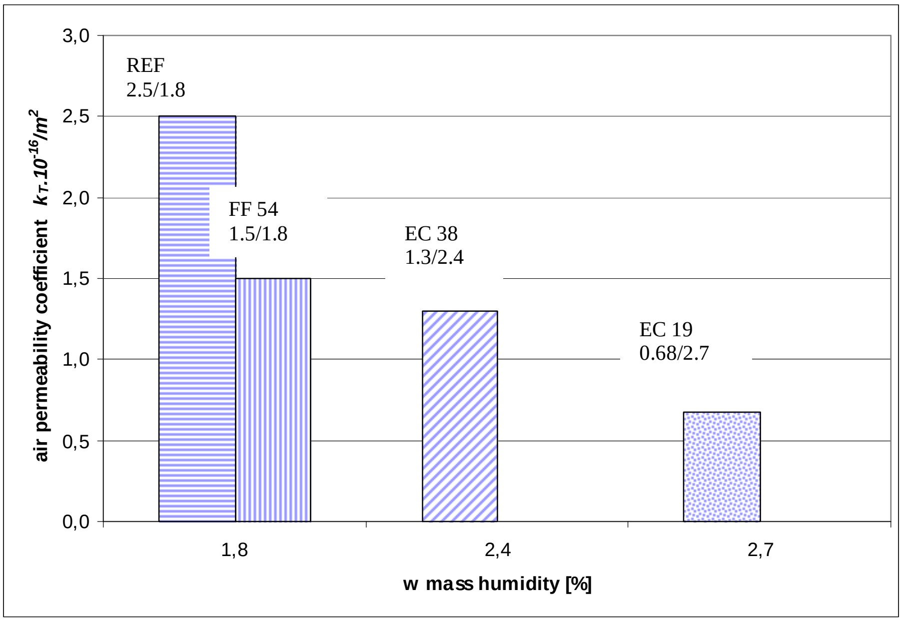

Fig. 4 Comparison the air permeability coefficients of tested concretes

From Fig. 4 it is evident that application of the high strength fibres approves itself by the decreasing of the k_T value, i.e. by improving the impermeability of the tested fibreconcretes. The permeability of the covercrete influences its moisture, i.e. the water volume or the water vapour in the pores of this covercrete. Another finding is a fact that at the identical storing conditions of the tested samples lasting more than 1 year, the porous structure of LWSC with the fibres retains higher moisture, though it is not too large. Probable interruption of the micro and macro-pores by the fibres will cause higher “permanent moisture” in the fibreconcretes. At comparable moisture of the light weight concretes EC 19 and EC 38 with the concretes REF and FF 54, the value k_T would be probably higher. The relations are compiled for common concretes, for LWSC we haven’t gained enough results up to now. It is assumed that the relation will be of similar character.

3 Conclusion

The experimental works dealing with the influence of different polymeric fibres on the air permeability both of common and LWSC are not of the same relevance. While the tests on the fine PE fibres were quite extensive (about 80 measurements), the tests on the high strength structural fibres have had only preliminary, informative character.

It seems that the application of the polymeric fibres improves not only deformation characteristics of both type of concretes, but it also contributes to the decreasing of their permeability. It can be expected that these fibreconcretes will be more durable.

Aknowledgements

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