SLOVAK INSTITUTE OF TECHNOLOGY

Faculty of Civil Engineering
Department of Concrete Construction and Bridges
Radlinského 11, 813 68 Bratislava

TEST REPORT

TOPIC:	**TESTING OF THE EFFECTIVENESS OF THE COATING MATERIAL XYPEX TO PREVENT GAS PERMEABILITY OF THE CONCRETE**
CUSTOMER:	**HYDROSTOP s.r.o.** **KARPATSKÁ 15, 058 01 POPRAD**
DATE:	**12.04.1994**
SITE OF THE TESTS:	**LABORATORY OF THE DEPARTMENT OF CONCRETE CONSTRUCTION AND BRIDGES**
REPORT DRAWN UP BY:	**DOC.ING.JURAJ BILČÍK, CSc.**
NUMBER OF TEXT PAGES:	**8**
ENCLOSURES:	**4**
LIST OF ORGANIZATIONS TO RECEIVE A COPY:	**3x HYDROSTOP s.r.o.** **1x KBKaM**

Doc.Ing.Juraj Bilčík, CSc.
vedúci katedry
Head of the Department

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1. GENERAL

By your purchase order No. 2/94 of February 21, 1994 you have commissioned us to test the effectiveness of the coating material XYPEX to prevent gas permeability of the concrete. On the delivery of this work was concluded contract No. 04/33/94.

2. THE PROBLEM

The permeability of the concrete to fluids and gases depends to a decisive degree on the so-called open porosity of the cement stone and its volume share of the total finished composite material. All aggressive substances causing a corrosion of the concrete or contributing to the corrosion of the reinforcement enter the concrete material through continuously "open" pores, which are big enough to allow free movement of molecules or ions.

The "open porosity" is basically identical with capillary pores which take up a volume in the hardened concrete that corresponds with the volume of the water evaporated.

Several research tasks are currently studying the possibility of establishing the potential durability of the concrete, above all the resistance of carbonation, by means of the tests of gas permeability. These tests enlarge the knowledge of the users of the concrete, especially on its behavior in the course of time, whereby they ensure the expected functional life span of the construction.

A concrete material which insufficiently prevents the transport of aggressive substances to its internal body often has to be protected by an additional coating. The measurement of gas permeability is one of the methods of evaluating the effectiveness of the coating in preventing the penetration of such substances.

3. CALCULATION AND MEASUREMENT OF GAS PERMEABILITY

The flow of the gas is ascertained and a coefficient of specific gas permeability is calculated by means of an absolute difference in gas pressure on two opposite sides of the test sample.

During the measurement of the specific gas permeability, the viscosity of the gas used is taken into account and the so-called laminar flow of gases is assumed, which means that the amount of air which passed through the sample is proportional to the induced differences in the pressure.

To establish the gas permeability of porous materials, the amount of the gas which penetrates through the sample is calculated from the equation:

$$Q = K. \frac{A}{n.H} . \frac{(P_e - P_a)(P_e + P_a)}{2p} \qquad (1)$$

where	Q	=	volume of the air forced through [m^3]
	K	=	specific gas permeability of the material tested [m^2]
	A	=	area of the test sample exposed to the air pressure
	n	=	viscosity of the gas [$N.s.m^{-2}$]
	H	=	thickness of the tested sample [m]
	Pa, Pe	=	absolute values of the input gas pressure [bar, 1 bar=10^5 $N.m^{-2}$]
	P	=	pressure, under which the amount of the air forced through is being measured

By simplification of the equation (1) we obtain an equation for the calculation of the specific permeability

$$K = \frac{Q.H.n}{A.t.p} \qquad (2)$$

The unit of the specific gas permeability, as it is deduced from equation (2), is m^2. Since, however, specific gas permeability has nothing to do with area, the unit "Perm" [Pm] became common, derived from the word (gas) permeability. Small values of specific gas permeability of the concrete are expressed in piko-Perms [pPm], 1 pPm=10^{-12} Pm.

4. EXPERIMENTAL TEST

4.1 Concrete underlay

The following material was used for the manufacture of the concrete cubes:

- Mined gravel sand from the sorting site Bratislava - Petržalka in the size fractions of 0-4, 4-8, 8-16 mm
- Cement SPC 325 - Rohožník
- Mixing water for the preparation and handling of the coating XYPEX was taken from the public water tap

Table 4.1 shows the composition and volume weight of the concrete.

Table 4.1 Concrete Composition and Volume Weight

CEMENT kg. m^{-3}	WATER kg. m^{-3}	GRAVEL SAND kg. m^{-3}			VOLUME WEIGHT. kg. m^{-3}
		0-4	4-8	8-16	
325	175	700	500	700	2342

Concrete cubes of the dimension of 150 mm were manufactured out of a concrete mixture and further compacted on a vibration table.

Out of the cubes, a core drill of an inner diameter of 100 mm obtained cylinders of a diameter of 100 mm.

By cutting such cylinders we obtained the test samples – cylinders of a diameter of 100 mm and a height of approximately 30 mm. During the drilling and cutting, water was used to cool the core drill or the frame saw disc.

The front surfaces of the test samples were cleaned of the free cement powder by compressed air. Later on, the samples were dried up to reach a stable weight at the temperature of 105°C and then they were left to cool down to the temperature of the testing chamber.

4.2 Measurement of Gas Permeability

Before the test, the temperature in the testing chamber and exact dimensions and mass of the test samples were measured. The test samples were set into the testing cell (Figure 1). A rubber packing was pressed to the testing body under the pressure of 500 kPa in order to prevent any penetration of air through the outer perimeter of the sample. Air was forced through the sample under a pressure of 100 kPa. The volume of the air forced through the sample was established by means of a measuring burette, in which a soap bubble has formed itself. A stopwatch measured the time it took 40.10^{-6} m^3 of air to pass the measuring burette.

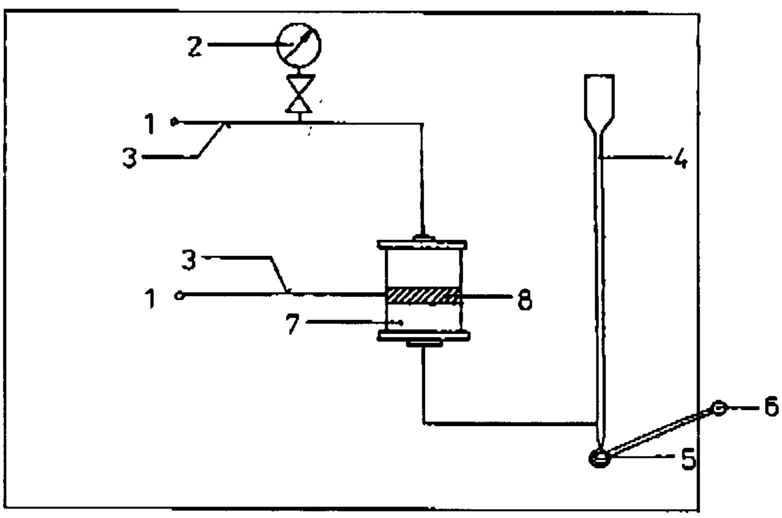

Figure 1 - Equipment for measuring the gas permeability:
1 – source of compressed air
2 – manometer, 3 – supply of compressed air
4 – bubble flow meter
5, 6 – a container with soap solution
7 – measuring cell, 8 – test sample

The dimensions, weight of samples and the gas permeability of the test samples measured are shown in the enclosure 1.

The samples tested were cleaned by a jet of water and a specialist of the firm Hydrostop s.r.o. applied a coating of Xypex Concentrate of a thickness of 0.8 mm on the wet sample. The samples were put with the side without a coating first into a water pan with a water level of about 1 mm. After 24 hours another coating of Xypex Concentrate was applied, again of a thickness of 0.8 mm and the samples were put back into the pan.

After 18 days since the application of the Xypex coating, the samples were again dried up at a temperature of 105°C to a stable weight and then they were left to cool down. On the 20th day we performed a second measuring of the gas permeability of the samples. The measurement values are indicated in Enclosure 2.

The samples were left in the testing chamber at a temperature of 22°C and, after eight days, their gas permeability was again measured.

Enclosure 3 shows the measured values of gas permeability.

4.3 Comparing results of the measurements of gas permeability

Enclosures 1-3 show the specific gas permeability of the concrete samples with and without a coating of Xypex. A basic orientation about the effective influence of the coating Xypex on the gas permeability of the concrete is provided by the ratio of the specific gas permeability of the samples without a coating and of the same samples with a Xypex coating, which is indicated in Table 4.2.

Table 4.2 Comparison of Gas Permeability

SAMPLE DESIGNATION	GAS PERMEABILITY WITHOUT COATING k $[m^2 . 10^{-16}]$	GAS PERMEABILITY WITH COATING k' $[m^2 . 10^{-16}]$	$\frac{k}{k'}$
X1	15.3	7.75	1.97
X2	10.8	5.35	2.01
X3	22.3	7.76	2.87
X4	13.2	8.73	1.51
X5	16	8.76	1.82
Average Values	15.5	7.67	**2.03**

4.4 Measurement of alkalinity

After the completion of the third measurement, the samples were broken. We were trying to establish whether the application of the Xypex coating lowered the pH under a value which is usually given as critical from the point of view of a possible corrosion of the concrete reinforcement. 2% solution of phenolphthalein in ethyl alcohol was used to establish the alkalinity of a fresh fracture of the broken concrete samples. A clear red coloration of this indicator gives a value of pH>9.2 (Photograph 2). For comparison the indicator was also applied to a fracture of the comparative samples without a Xypex coating (Photograph 1).

5. EVALUATION

5.1 Tests of gas permeability

In order to be able to evaluate the influence of the coating material Xypex on the diffusion properties of the concrete, the values of gas permeability of concrete samples with and without a Xypex coating were experimentally ascertained. Table 4.2 shows an average value of gas permeability of the samples, 18 days after a Xypex coating was applied, to be k^1=7,67.10^{-6} m^2. A comparison with the value of gas permeability before the application of a Xypex coating (k= 15.5 x 10^{-6}) makes it obvious that the Xypex coating has caused the average gas permeability to decrease to half.

A comparison of values ascertained during the second and third measurements is shown in Table 5.1.

Table 5.1 Comparison of Gas Permeability after 8 days

SAMPLE DESIGNATION	GAS PERMEABILITY MEASURED 30.03.94 [m^2. 10^{-16}]	GAS PERMEABILITY MEASURED 8.04.94 [m^2. 10^{-16}]
X1	7.75	6.98
X2	5.35	5.35
X3	7.76	7.76
X4	8.73	8.73
X5	8.76	8.76

The values in Table 5.1 show that the third measurement established, with the exception of the sample X1, the same values as the second measurement. This means that a storage of samples with applied Xypex coating in a dry environment for the time period of 8 days did not affect the gas permeability of the concrete samples.

5.2 Measurement of Alkalinity

A measurement of the alkalinity of fresh fracture of the concrete samples by means of an acid-based indicator changing its color at values of pH>9.5 did not show a decrease of alkalinity below this value critical for the steel reinforcement of the concrete.

A decrease of alkalinity below the indicated value was not ascertained even under the coating of Xypex.

To objectively evaluate the influence of Xypex on the condition of the concrete reinforcement, we recommend carrying out long-term tests of carbonation.

6. CONCLUSION

The subject of this report is the testing of the effectiveness of the coating material Xypex to decrease gas permeability of the concrete. The results of the performed tests are as follows:

- After 18 days of wet handling of samples with an applied coating of Xypex a decrease of gas permeability of the concrete samples to about half was achieved;
- Storage in a dry environment of samples with a Xypex coating lasting 8 days had no effect on their gas permeability;
- 28 days after the application of a Xypex coating, it was ascertained that the value of pH of the concrete was higher than 9.5.

Doc.Ing.Juraj Bilčík,CSc
zodpovedný riešiteľ

(Researcher in Charge)

In Bratislava on April 12, 1994

Enclosure 1

LABORATORY OF THE DEPARTMENT OF CONCRETE CONSTRUCTION AND BRIDGES, FACULTY OF CIVIL ENGINEERING, SLOVAK INSTITUTE OF TECHNOLOGY

PROTOCOL OF TESTS OF GAS PERMEABILITY OF THE CONCRETE

DATE OF MANUFACTURE: DATE OF TEST: 9.3.1994 TEMPERATURE: 22°C VOLUME MEASURED: $Q=40.10^{-6}m^3$

SAMPLE DESIGNATION	WEIGHT	HEIGHT	DIAMETER	AREA	AIR PRESSURE	TIME [s]			GAS PERMEABILITY	NOTE
	[g]	H [m]	[m]	A [m²]	P [kPa]	t_1	t_2	Øt	*k* [Perm]	
X1	549	31.4×10^{-3}	0.100	7.854×10^{-3}	105	18	18	18	1.53×10^{-15}	
X2	513	29.5×10^{-3}	0.100	7.854×10^{-3}	105	24	24.2	24.1	1.08×10^{-15}	
X3	533	31.2×10^{-3}	0.100	7.854×10^{-3}	105	12.3	13.1	12.7	2.23×10^{-15}	
X4	529	29.8×10^{-3}	0.100	7.854×10^{-3}	102	20	20.8	20.4	1.32×10^{-15}	
X5	500	28.7×10^{-3}	0.100	7.854×10^{-3}	103	16	16.2	16.1	1.6×10^{-15}	

Gas Permeability $k = \frac{Q.H.n}{A.t.p.}$

Enclosure 2

LABORATORY OF THE DEPARTMENT OF CONCRETE CONSTRUCTION AND BRIDGES, FACULTY OF CIVIL ENGINEERING, SLOVAK INSTITUTE OF TECHNOLOGY

PROTOCOL OF TESTS OF GAS PERMEABILITY OF THE CONCRETE: WITH A XYPEX COATING

DATE OF MANUFACTURE: DATE OF TEST: 30.3.1994 TEMPERATURE: 22°C VOLUME MEASURED: $Q=40.10^{-6} m^3$

SAMPLE DESIGNATION	WEIGHT [g]	HEIGHT H [m]	DIAMETER [m]	AREA A [m^2]	AIR PRESSURE P [kPa]	TIME [s] t_1	t_2	Øt	GAS PERMEABILITY k [Perm]	NOTE
X1	572	$33.7x10^{-3}$	0.100	$7.854x10^{-3}$	98	41	41	41	$7.75x10^{-16}$	
X2	534	$30.3x10^{-3}$	0.100	$7.854x10^{-3}$	97	54.2	53.8	54	$5.35x10^{-16}$	
X3	553	$33.4x10^{-3}$	0.100	$7.854x10^{-3}$	100	40	39.6	39.8	$7.76x10^{-16}$	
X4	550	$32.4x10^{-3}$	0.100	$7.854x10^{-3}$	98	35	35	35	$8.73x10^{-16}$	
X5	518	$30x10^{-3}$	0.100	$7.854x10^{-3}$	96	33	33	33	$8.76x10^{-16}$	

Gas Permeability $k = \frac{Q.H.n}{A.t.p.}$

LABORATORY OF THE DEPARTMENT OF CONCRETE CONSTRUCTION AND BRIDGES, FACULTY OF CIVIL ENGINEERING, SLOVAK INSTITUTE OF TECHNOLOGY

PROTOCOL OF TESTS OF GAS PERMEABILITY OF THE CONCRETE: WITH A XYPEX COATING

DATE OF MANUFACTURE: DATE OF TEST: 8.04.1994 TEMPERATURE: 22°C VOLUME MEASURED: $Q=40.10^{-6}m^3$

SAMPLE DESIGNATION	WEIGHT	HEIGHT	DIAMETER	AREA	AIR PRESSURE	TIME [s]			GAS PERMEABILITY	NOTE
	[g]	H [m]	[m]	A [m²]	P [kPa]	t_1	t_2	Øt	k [Perm]	
X1	572	$33.7x10^{-3}$	0.100	$7.854x10^{-3}$	95	47.4	46.6	47	$6.98x10^{-16}$	
X2	534	$30.3x10^{-3}$	0.100	$7.854x10^{-3}$	100	52	52	52	$5.35x10^{-16}$	
X3	553	$32.4x10^{-3}$	0.100	$7.854x10^{-3}$	97	42.1	49.9	42	$7.76x10^{-16}$	
X4	550	$32.4x10^{-3}$	0.100	$7.854x10^{-3}$	95	37	37	37	$8.73x10^{-16}$	
X5	518	$30x10^{-3}$	0.100	$7.854x10^{-3}$	96	33	33	33	$8.76x10^{-16}$	

Gas Permeability $k = \frac{Q.H.n}{A.t.p.}$

7. Photograph Enclosure

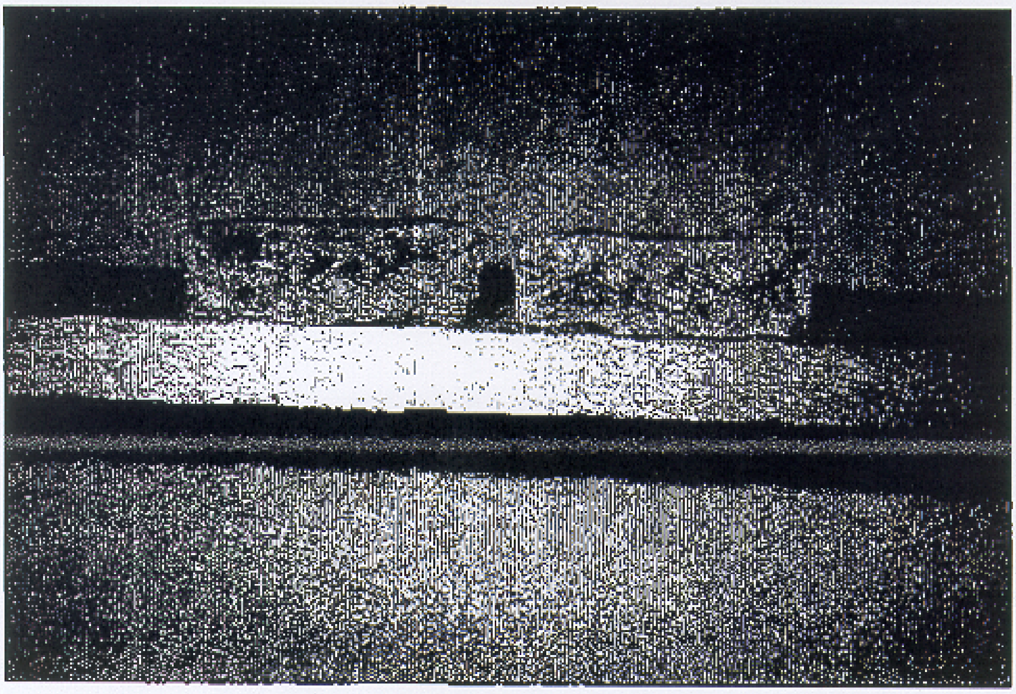

Photo 1 Measuring of alkalinity of the concrete by phenolphthalein test on broken samples **without** a coating.

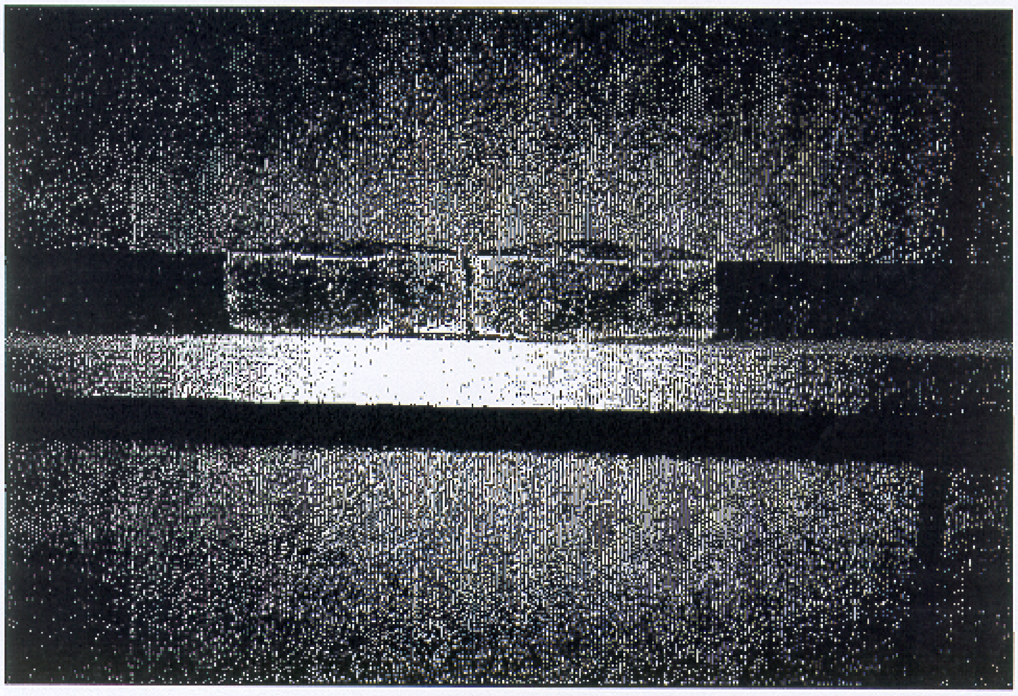

Photo 2 Measuring of alkalinity of the concrete by phenolphthalein test on broken samples **with** a Xypex coating.