Test Report: Nr.: **407.039** Date: **2013-05-08**

PENETRON - System for protection and repair of the surface of concrete structures

Client:	Penetron International Ltd. 45 Research Way, Suite 203 East Setauket, 11733 New York USA
Subject:	System for protection and repair of the surface of concrete structures with the trade name PENETRON
Task:	Examination of the resistance against pressured water and chloride ion penetration
Order:	Written, dated 2012-02-09
Date of sampling:	---
Location of sampling:	---
Receipt of samples:	2012-02-13
Ref:	DI Papp / Vyc

OFI Technologie & Innovation GmbH
t: +43 1 798 16 01 – 0
f: +43 1 798 16 01 – 8
office@ofi.at
www.ofi.at

Firmensitz:
1030 Wien, Franz-Grill-Straße 5, Arsenal, Objekt 213
Weitere Standorte:
1110 Wien, Brehmstraße 14a
2700 Wr. Neustadt, Viktor Kaplan Straße 2 / Bauteil C

Bankverbindung: UniCredit Bank Austria AG – BLZ 12000 – Kto.-Nr.: 52085 521 211 – SWIFT/BIC: BKAUATWW – IBAN: AT84 1200 0520 8552 1211
Firmenbuch-Nr.: FN 230299 a, HG Wien, Gerichtsstand Wien – UID ATU 56534913

1 SCOPE OF WORK

According to the order of the client two different concrete types with the designation CEM III-A (blastfurnace slag cement) and CEM II-A/V (fly ash Portland cement) according to EN 197-1 had been coated with the product PENETRON of the producer Penetron International Ltd. (East Setauket, 11733 New York, USA), which can be used as a system for the protection and repair of the surface of concrete structures, and subjected to an examination of

- the resistance against pressing water in accordance to section 4.7 of DIN 1048 and
- the resistance against chloride ion penetration in accordance to the reglementation AASHTO T 259-02 (2012).

The results shall be compared to those achieved on uncoated concrete types with the designation CEM III-A and CEM II-A/V according to EN 197-1.

2 SCOPE OF APPLICATION

The results given in this report have been obtained under the specific conditions of the individual tests. They shall serve as a proof for the client of the conformity of those samples tested according, to the requirements of the product standard(s) given.

3 SAMPLE MATERIAL

A representative of the client handed over on the 2012-02-09 a sufficient amount of the product with the trade name PENETRON to the ***ofi*** - Technologie & Innovation GmbH (subsequently ***ofi***).

The concrete samples with the designation CEM III-A and CEM II-A/V according to EN 197-1 had been mixed and produced on 2012-06-01 by the institute BTI (Linz, Austria) and arrived on the site of ***ofi*** on the 2012-06-19.

4 TESTS

All tests were carried out between 2012-06-19 and 2013-05-08 in the individual technical departments within the scope of competence of the authorised signatories according to the ***ofi***-QM-Manual.

5 CONCRETE SLABS AND PREPARATION OF SAMPLES

The concrete slabs used for further tests can be described as follows:

- CEM III-A (blastfurnace slag cement) according to EN 197-1 composed out of 35 % up to 64 % CEM I and 36 % up to 65 % blastfurnace slag. The water/cement ratio of the samples was 0,57. The mixing protocol can be seen in annex 1 (comprises 1 page).
- CEM II-A/V (fly ash Portland cement) according to EN 197-1 composed out of 80 % up to 94 % CEM I and 6 % up to 20 % fly ash. The water/cement ratio of the samples was 0,48. The mixing protocol can be seen in annex 2 (comprises 1 page).

The samples had a thickness of 150 mm (5.91 inch) and a total top edge surface of 22 500 mm² (34.93 inch²). These dimensions of the samples fulfill the requirement in DIN 1048 as well as AASHTO T 259-02 (2012).

After the mixing and production of the sample on 2012-06-01, they had been cured for a period of 28 days at standard climate (23 °C / 50 % rel. humidity respectively 73.4 °F / 50 % rel. humidity).

The product PENETRON is sold by the client as a concentrate. Therefore as stated in the producers instructions 100 parts of the concentrate had been mixed and stirred well with 40 part of water. The concrete slabs were roughened by using abrasive paper.

In a next step the coating was applied twice with a surface area mass of approximately 800 g/m² each. The subsequent three days the coated surfaces were kept moist by spraying water on them. In a final step the samples were returned to standard climate for a period of 7 days again.

6 RESISTANCE TO PRESSING WATER

The resistance against pressing water was determined in accordance to section 4.7 of the DIN 1048 while subjecting the samples to an adopted pressure regime agreed on with the clients' representative.

Two concrete samples of each designation CEM III-A and CEM II-A/V had been set under pressured water. Hereby the pressure was increased with a pressure rate of

1 bar (14.5 psi) per hour until a maximum pressure of 20 bar (290.1 psi) was reached. This pressure of 20 bar (290.1 psi) was kept over a period of 72 h.

After this first test was finished, one sample per designation was put aside for further examinations.

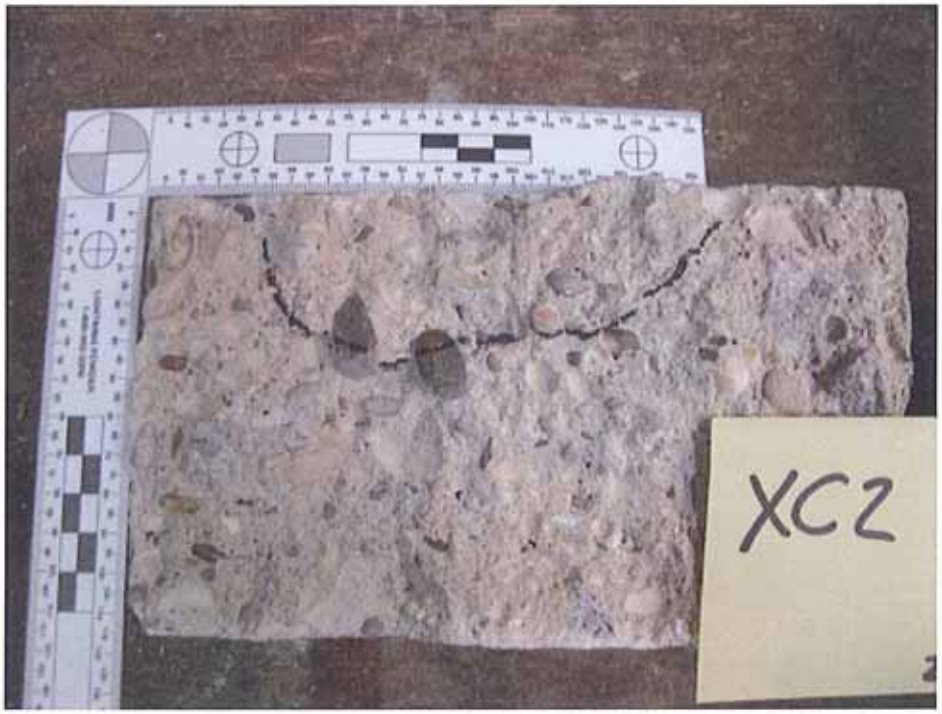
The remaining sample with the designation CEM III-A was stored in an oven at 30 °C (86 °F) for 7 days and re-subjected to the pressure test. Hereby the pressure was increased with a pressure rate of 1 bar per hour until a maximum pressure of 20 bar (290.1 psi) was reached. This pressure of 20 bar (290.1 psi) was kept again over a period of 72 h.

After the second test was finished, also this sample was put aside for further examinations. All samples were split and the penetration of water marked with a line. The results (Picture 1 up to Picture 5) are summarized in table 1.

Additionally the impact of pressing water of the macroscopic structure of the concrete in the wet and dry areas was investigated and documented by using a scanning electron microscope (SEM) (Picture 6 up to Picture 9).

Picture 1: CEM III-A: Uncoated and subjected to two pressure cycles (20 bar resp. 290.1 psi over 72 h)

Picture 2: CEM III-A: Coated, subjected to one pressure cycle (20 bar resp. 290.1 psi over 72 h)



Picture 3: CEM III-A: Coated, subjected to two pressure cycles (20 bar resp. 290.1 psi over 72 h)

Picture 4: CEM II-A/V: Uncoated and subjected to two pressure cycles (20 bar resp. 290.1 psi over 72 h)

Picture 5: CEM II-A/V: Coated and subjected to one pressure cycle (20 bar resp. 290.1 psi over 72 h)

Table 1: Maximum penetration depth of water caused by pressing water (20 bar resp. 290.1 psi over 72 h)

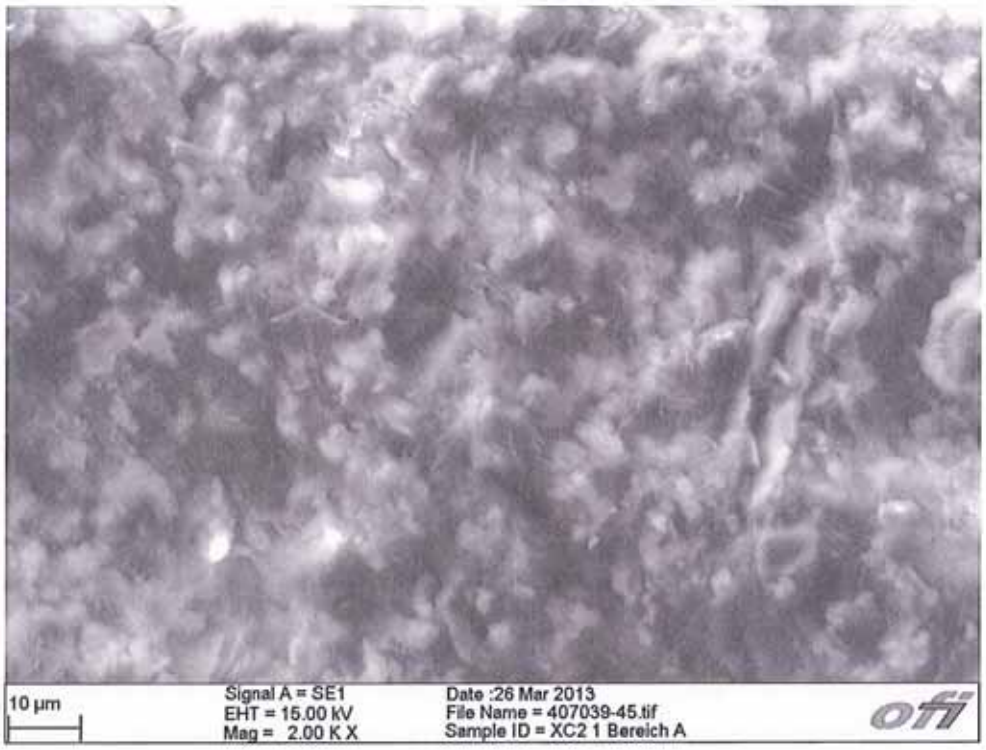
Designation	Coating and test procedure	Max. penetration depth in mm
CEM III-A (blastfurnace slag cement)	No coating - subjected to two pressure cycles	70
	Coated - subjected to one pressure cycle	45
	Coated - subjected to two pressure cycles	50
CEM II-A/V (fly ash Portland cement)	No coating - subjected to two pressure cycle	90
	Coated - subjected to one pressure cycle	30

Results:

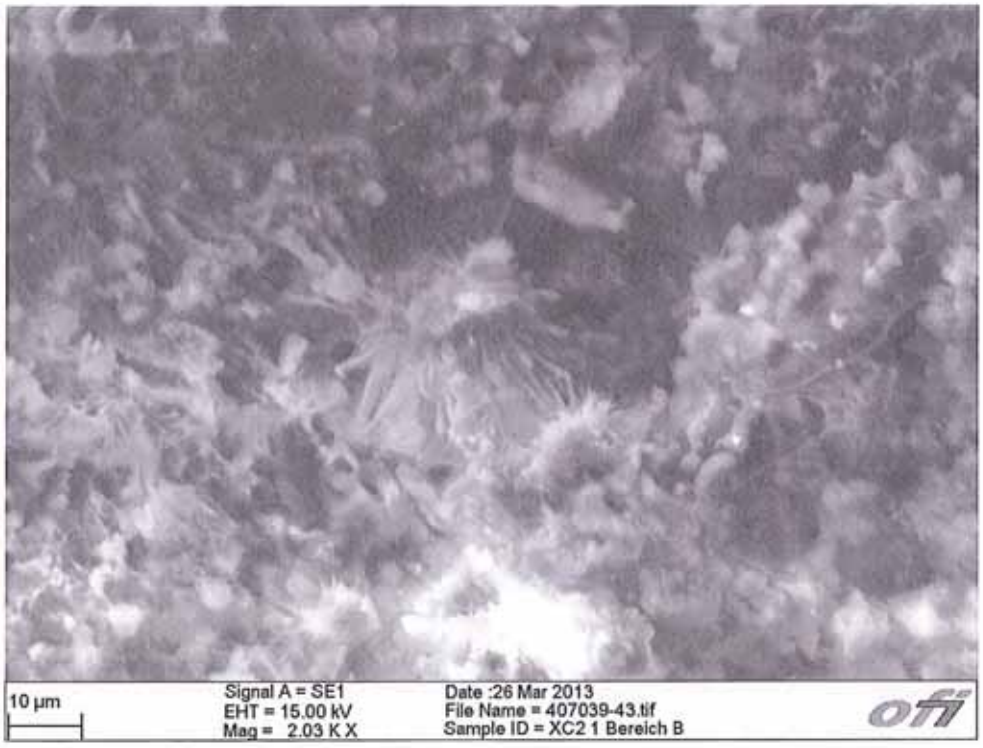
The results summarized in Table 1 show a significant lower penetration depth of the coated samples, which had been subjected to one resp. two pressure cycles compared to the uncoated ones.

While on the uncoated samples, which were subjected to two pressure cycles no significant differences between the dry and the wet areas according to the morphological structure could be found, the coated sample CEM III-A did show a significant higher density of crystalline structures in the wet area (Picture 7) compared to the dry area (Picture 6) after already one pressure cycle.

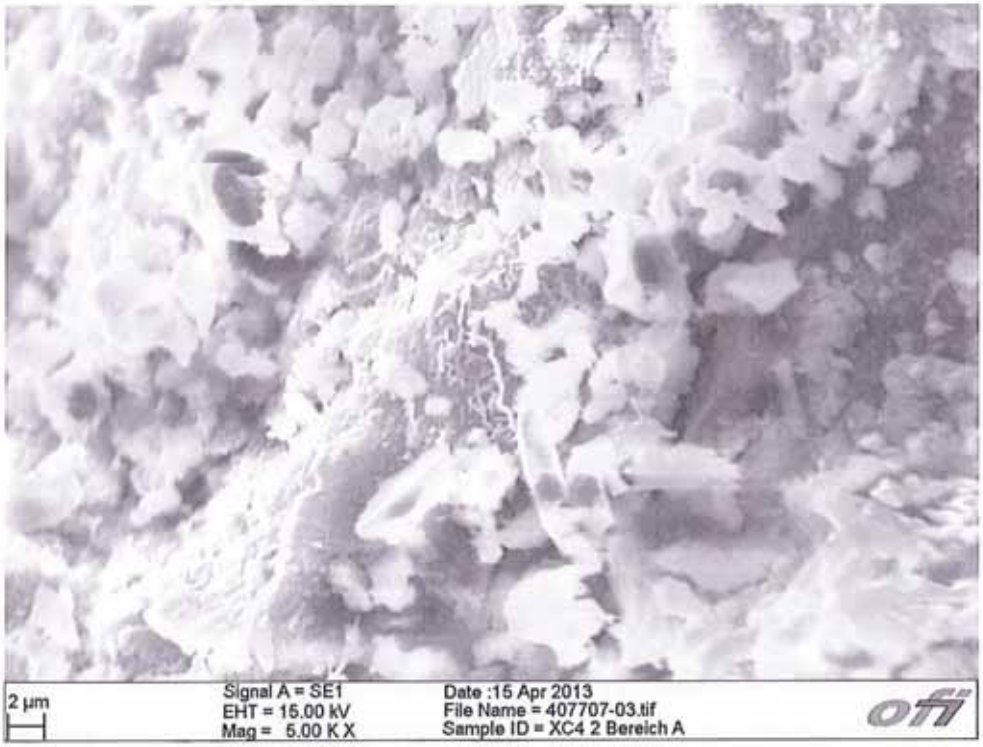
The same effect was observed on the samples out of CEM II-A/V after two pressure cycles (Picture 8 and Picture 9).



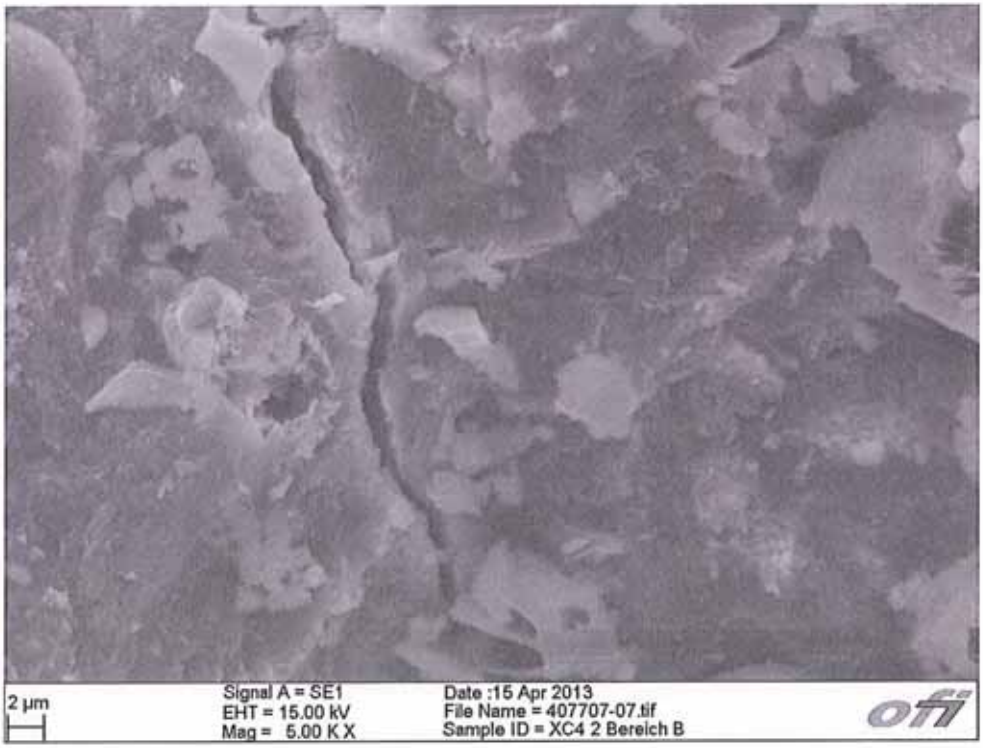
Picture 6: CEM III-A: Coated, subjected to one pressure cycles – SEM in dry area



Picture 7: CEM III-A: Coated, subjected to one pressure cycles – SEM in wet area



Picture 8: CEM II-A/V: Coated, subjected to one pressure cycles – SEM in wet area



Picture 9: CEM II-A/V: Coated, subjected to one pressure cycles – SEM in dry area

7 RESISTANCE TO CHLORIDE ION PENETRATION

The samples described in section 5 of this report had been stored after the coating procedure for yet another period of 28 days at standard climate (23 °C / 50 % rel. humidity respectively 73.4 °F / 50 % rel. humidity). The surface abrasion as described in section 4.1 of AASHTO T 259-02 was not performed.

After that ageing dams had were fixed on the coated top edge of the samples and were sealed against the slabs. In a last step, before starting the test, all samples were returned to standard climate for another period of 13 days. One sample, which was used as a control sample, was subjected to the same procedure with any dam.

Those slabs with dams were subjected to continuous ponding with a 3 per cent sodium chloride solution to a depth of approximately 13 mm (0.5 inch) for 90 days at standard climate. To retard evaporation of the solution a glass plate was placed over the solution respectively the dams in such a manner, that the surface is not completely sealed from the surrounding atmosphere. The depth of the solution was continuously monitored and if necessary additional solution was added to maintain the depth of 13 mm (0.5 inch).

After ponding for a period of 90 days the 3 per cent sodium chloride solution and the dams were removed, all samples were dried again for another 28 days in standard climate and the surface was wire-brushed until all salt crystal build-up was removed. In a next step samples for the chloride ion analysis were taken from the slabs deviating from AASHTO T 259-02 with the following depths:

- 1.6 mm (0.063 inch) to 10 mm (0.394 inch)
- > 10 mm (0.394 inch) to 20 mm (0.787 inch)
- >20 mm (0.787 inch) to 30 mm (1.181 inch)

The chloride contents of each sample including those, which were not subjected to in accordance with procedure A (Acid-soluble chloride ion content and water-soluble chloride content) of AASHTO T 260-97 (2009) after crushing and grinding the samples to powder. Deviating from AASHTO T 260-97 (2009) the chloride content was determined by using ion chromatography. The results are summarized in Table 2.

Table 2: Chloride ion penetration (average values of mass-%)

Measuring Parameter	Measuring depth (mm resp. inch)	CEM III-A (blastfurnace slag cement)			CEM II-A/V (fly ash Portland cement)		
		uncoated unponded	uncoated ponded	coated ponded	uncoated unponded	uncoated ponded	coated ponded
Total chloride ion value	1.6 mm (0.063 inch) to 10 mm (0.394 inch)	---	0.150	0.075	---	0.159	0.083
	> 10 mm (0.394 inch) to 20 mm (0.787 inch)	---	0.022	0.010	---	0.019	0.007
	>20 mm (0.787 inch) to 30 mm (1.181 inch)	---	0.014	0.006	---	0.016	0.007
Baseline chloride content	1.6 mm (0.063 inch) to 10 mm (0.394 inch)	0.007	---	---	0.007	---	---
	> 10 mm (0.394 inch) to 20 mm (0.787 inch)	0.004	---	---	0.004	---	---
	>20 mm (0.787 inch) to 30 mm (1.181 inch)	0.004	---	---	0.006	---	---
Calculated absorbed chloride ion value	1.6 mm (0.063 inch) to 10 mm (0.394 inch)	---	**0.143**	**0.068**	---	**0.152**	**0.076**
	> 10 mm (0.394 inch) to 20 mm (0.787 inch)	---	**0.018**	**0.006**	---	**0.015**	**0.003**
	>20 mm (0.787 inch) to 30 mm (1.181 inch)	---	**0.010**	**0.002**	---	**0.010**	**0.001**

This test report no. **407.039**

comprises 12 sheet(s) 2 table(s), 9 figure(s), 2 enclosure(s).

Testing staff	Director in charge Department piping systems
Patrick Vycudilik	DI Udo Pappler