

Test Report Nr. 173969/2e

Client: **NORD RESINE S.r.l.**
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Test Assignment: Test of the tunnel coating
Test Object: NORPHEN SW SMALTO

Client Ref. Nr.:
Client: **Dott. Francesco Chisso**
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PRELIMINARY REPORT

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1 Introduction

NORPHEN SW SMALTO is a tunnel coating for mineral substrates, designed as a protection of concrete from aggressive media for motorway tunnels and galleries. The coating had to be examined with various tests for its suitability as a tunnel coating.

2 Sample description

3 plates 300 x 200 x 50 mm of P 300-concrete coated with NORPHEN SW SMALTO

4 special films "Leneta" 420 x 165 mm coated with NORPHEN SW SMALTO

6 free-standing films of A4-format of NORPHEN SW SMALTO

All samples were prepared by the client.

3 Experimental conditions, results

3.1 Behaviour under jet of steam

Standard: DIN 4768 and ISO 8503/4.

Method: EMPA

Sample: coated concrete plate

Experimental procedure: a jet of steam (temperature. ca. 90° C) is directed towards the coated concrete plate during 30 s

Requirement: There have to be no blisters, cracks or flakes

Result: There were no blisters, cracks or flakes

3.2 Falling ball test

Method: RdT 31 - a- 1.2, (Coating mineral materials for sealing of stockrooms and trans-shipment centres, former TTV appendix 2, clause 31, paragraph a. 1), Method 8.9, issue of 17.12.1992

Sample: coated concrete plate

Experimental procedure: A 1 kg steel ball falls down from the height of one meter 5 times at a horizontally placed coated concrete plate in different places

Requirement: The coating have not to be cracked or peeled from the substrate at the impact places

Result: The coating was not cracked and peeled at the impact places

3.3 Resistance to alkaline solutions

Method:	EMPA
Sample:	coated concrete plate
Experimental procedure:	A coated concrete plate is to be placed in a sodium hydroxyd solution ($c = 0.1 \text{ mol/l}$, pH 13) for two weeks at 23°C
Requirement:	No signs of attack
Result:	There were no signs of attack

3.4 Evaluation of cleanability

Method:	similar to DIN 53 778-2 (without pencil marks)
Sample:	The coating of $262 \pm 52 \mu\text{m}$ thickness was applied by the client to Leneta-films
Experimental procedure:	After 30 days storage of the coated Leneta-films at 23 °C and 50% r.h. 3 lines of wax crayon and 3 lines of charcoal were applied to the coating. After 24 hours storage at 23 °C and 50% r.h. the test of cleanability was carried out similar to DIN 53778-2.
Requirement:	After 800 scrubbing cycles the lines have to be removed
Result:	The lines were removed completely

3.5 Evaluation of wash and scrub resistance

Method:	DIN 53 778-2
Sample:	coated Leneta-film (see 3.4)
Experimental procedure:	The coating was subjected to 5000 scrubbing cycles
Requirement:	After 5000 scrubbing cycles the coating has not to be worse as it is shown in DIN 53 778-2
Result:	The coating was intact

3.6 Water vapour permeability

Method:	Dr. Lyssy
Sample:	free-standing film
Experimental procedure:	see annex 1, ASTM E 398-83
Temperature:	23 °C
Humidity difference	85% rel. humidity (100 % to 15%)
Surface area of the film:	0.0050 m ²

Result:

Water vapour permeability in $[g/m^2 \cdot 24 h]$

Sample	1	2	3
film thickness s [μm]	247 ± 52		
permeation rate W [$g/m^2 \cdot 24 h$]	ca. 5		

Calculation:

Sample	1	2	3
$K_D = W/\Delta p$ [$mg/(m^2 \cdot h \cdot Pa)$]	0.0875		
$s_d = \lambda_{D-air}/K_D$ [m]	8.2		
$\mu = s_d/s$ [-]	33300		

The s_d -value [m] describes the diffusion equivalent air thickness, K_D the transmission rate of water vapour and Δp the difference of the water vapour pressure at the experimental conditions (here 2378 Pa). The μ -value (diffusion resistivity coefficient) is the ratio of the water vapour permeation rate through the tested sample and a layer of motionless air of the same thickness at the same temperature.

Remark: Because of the long duration of the measurement of one sample (more than one week), only one sample has been measured. The further measurements are still going.

3.7 Diffusion of chloride

Method: similar to ASTM A 775 - 93

Sample: free-standing film

Test media: On the one side of the film the solution of sodium chloride ($c = 3$ mol/l), on the other side deionized water

Experimental procedure: The conductivity is measured and the amount of diffused chloride is calculated with the help of the calibration curve

Result:

Chloride permeation rate W in $[g/m^2 \cdot 24 h]$

sample	1	2
film thickness s [μm]	316 ± 32	329 ± 58
permeation rate W [$g/m^2 \times 24 h$]	$< 1 \times 10^{-3}$	$< 1 \times 10^{-3}$

For a film thickness of about 320 μm , the amount of diffused chloride is less than 1 $mg/m^2 h$.

3.8 Measurement of gloss

Method: ISO 2813
 Sample: coated concrete plate
 Measuring instrument: gloss reflectometer "micro TRI gloss"
 Experimental setup: 60 and 85°, calibrated on 95 or 99 gloss units
 Result:

Percentage gloss of the coating for 60° and 85° experimental setup

Experimental setup	individual results	mean value with standard deviation
60°	30 - 29 - 29 - 28 - 28 - 26 - 27	28.1 ± 1.2
85°	81 - 77 - 82 - 81 - 78 - 76 - 79	79.1 ± 2.1

3.9 Adhesion test

Standard: DIN EN 24624
 Sample: coated concrete plate
 Experimental procedure: Sand-blasted screw-tops of M8 screws were glued onto the coated surface of the sample with a two-component solvent-free adhesive. After the curing time of 24 h the coating was cut off along the contour of the screw-top with a drill. Afterwards the screw was pulled off at right angle to the substrate with a pull-off measuring instrument
 Measuring instrument: Dyna Z 5 of the firm Proceq Sa Zürich, a pull-off tester with the maximal force of 5.00 kN

Result:

Pull-off force in [N/mm²]

sample	individual results [N/mm ²]	location of failure
1	5.0	in concrete
2	6.3	in concrete
3	5.0	in concrete
4	4.4	in concrete
5	9.5	2/3 in concrete, 1/3 in adhesive
6	7.0	in concrete
7	6.3	in concrete
8	6.5	in concrete
mean value [N/mm²]	6.3 ± 1.5	

4 Comment

The NORPHEN SW SMALTO coating of 247 μm thickness has the s_D -value of 8.2 m, i.e., a low water vapour permeability. This s_D -value has been obtained from only one measurement. The further measurements are still going.

All other requirements for the tunnel coating have been fulfilled.

P.S. The testes samples will be kept for 3 months. After this period they will be disposed if not claimed.

Annex 1**Measurement of the water vapour permeation rate (ASTM E 398, Method of Dr. Lyssy)**

The water vapour permeation rate is determined on 3 samples according to the isostatic method of Dr. Lyssy. The sample is placed between a chamber of saturated atmosphere and a chamber of relatively low humidity containing a resistive solid state moisture sensor. The permeation area is 50 cm². The temperature of the instrument is kept constant. The instrument can be used at temperatures in range of 5 - 70°C. The precision of the temperature is in the range of $\pm 0.1^\circ\text{C}$.

The humidity in the chamber with lower humidity is initially adjusted to 14.5%. Due to the humidity difference between the two chambers water diffuses into the chamber with lower humidity, and time to be used for a humidity increase to 15.5% is measured. After calibration with a film of known permeation rate, the permeation rate of the sample can be determined.

Using the permeation rate values the diffusion resistivity coefficient and the diffusion equivalent layer thickness can be calculated (based on a permeation coefficient of H₂O in air of 0.72 mg/m · h · Pa at 23°C).