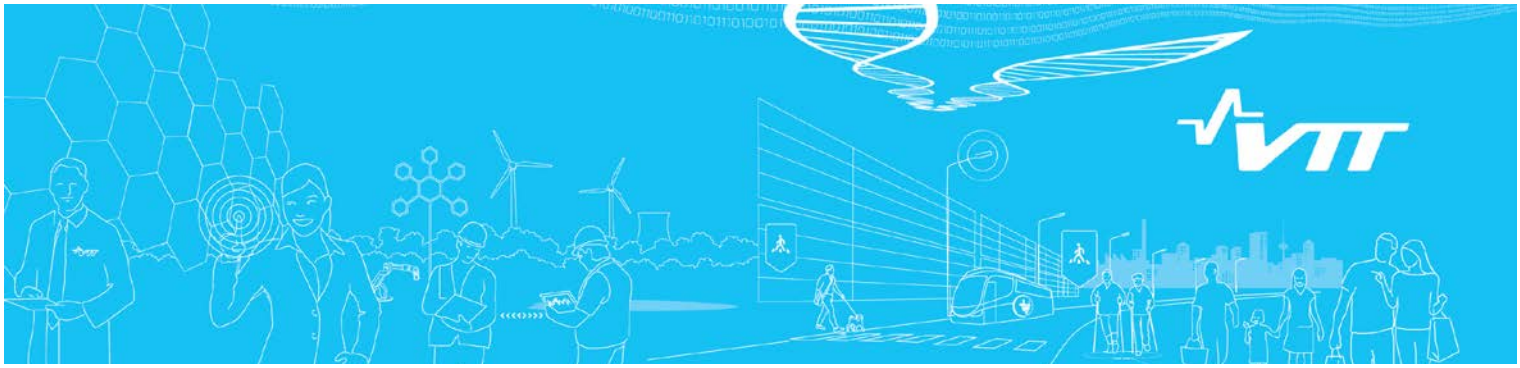

CUSTOMER REPORT

VTT-CR-01211-16/EN
REPLACES RESEARCH REPORT VTT-R-01292-14/EN

Protective agents of concrete SILKO-tests 2016

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Confidentiality: Public

Report's title

Protective agents of concrete SILKO-tests 2016

Customer, contact person, address	**Order reference**
Finnish Transport Agency, Ossi Räsänen, Department of Engineering Structures, P.O. Box 33, FI-00521 Helsinki, Finland	Livi/773/02.01.12/2016
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Summary

This is an unofficial translation of the Finnish research report. In case of interpretation disputes the Finnish report.

This test programme is an updated version of the test programme VTT-R-01292-14/EN.

These test instructions are used in examining the suitability of protective agents for concrete engineering structures of the orderer (developer). Suitable materials are published in SILKO-directions which are available in the internet www.liikennevirasto.fi/palveluntuottajat/ohjeluettelo.

There are four types of protective agents for concrete; hydrophobic impregnation agents, pore filling impregnation agents, coatings and anti-graffiti agents. Anti-graffiti agents are further divided in sacrificial and cleanable agents. The harmonized European product standard EN 1504-2 covers the before mentioned products except for the sacrificial anti-graffiti agents. The products covered by EN 1504-2 must have CE marking, DoP according to EN 1504-2 and AVCP class 2+. The cleanable anti-graffiti agents may be hydrophobic impregnation agents, pore filling impregnants or coatings and their requirements are the same as those of the product group in question.

Part of the SILKO-tests are obligatory and part of them are voluntary. On the bases of the results of the obligatory tests the orderer decides about the applicability of the material for the orderers projects. The voluntary tests are carried out to prove that a material has a special property suitable for a special case.

Confidentiality	Public

Espoo 17.3.2016

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Distribution (customer and VTT)

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Contents

1. Introduction

These test instructions are used in examining the suitability of protective agents for concrete engineering structures of the orderer (developer). These instructions concern hydrophobic impregnation agents, pore filling impregnants, coatings, sacrificial anti-graffiti agents and cleanable anti-graffiti agents. The test programme is prepared corresponding to Finnish outdoor environments using as much European test standards as possible. Part of the SILKO-tests are obligatory and part of them are voluntary. On the bases of the results of the obligatory tests the orderer decides about the applicability of the material for the orderers projects. The suitable materials are published in SILKO-directions which are available in the internet www.liikennevirasto.fi/palveluntuottajat/ohjeluettelo.

The harmonized European product standard EN 1504-2 covers the before mentioned products except for the sacrificial anti- graffiti agents. The products covered by EN 1504-2 must have CE marking, DoP according to EN 1504-2 and AVCP class 2+. The cleanable anti-graffiti agents may be hydrophobic impregnation agents, pore filling impregnants or coatings and their requirements are the same as those of the product group in question.

The test specimens for SILKO-tests are treated with protective agent by the product agent under the surveillance of the representative of the test laboratory. Any exception to this procedure should be noted in the test report.

2. Product groups and their test programmes

Part of the SILKO-tests are obligatory and part of them are voluntary. The obligatory tests must be carried out on all the materials that are wished to become SILKO products. The voluntary tests are carried out to prove that a material has a special property suitable for a special case. The properties of different groups of materials that are tested are given in chapter 3, along with the test methods.

Other than the European test methods of the test programme are described in chapter 4.

3. SILKO test programmes and criteria of protective agents of concrete

3.1 Hydrophobic impregnation agents

Property	Test method	Criterion and grading			
		+	++	+++	++++
Obligatory tests					
Water permeability	EN 13580	Absorption rate, % of reference			
		< 15	≤ 10	≤ 5	
Alkali resistance	EN 13580	Absorption rate after immersion in alkali, 10 % of reference			
Water vapour	EN 13579	Drying rate coefficient (Mean drying rate of treated test cubes/ Mean drying rate of untreated test cubes * 100), % Class I: > 30 Class II: > 10			
Chloride permeability	NT BUILD 515	Chloride content at depth 10-20 mm, % of reference			
		≤ 100	≤ 20	≤ 15	≤ 8
Frost salt durability	EN 13581	The loss of mass of the surface of the impregnated specimen must occur at least 20 cycles later than that of the not impregnated specimen.			
Penetration depth	EN 1504-2	Penetration depth, mm			
		≥ 2	≥ 5	≥ 10	≥ 15
Voluntary tests					
Carbonation prevention	NT BUILD 357 CO_2-content 1 % (Chapter 4.1)	Carbonation depth, % of reference			
		≤ 100	≤ 60	≤ 20	
Cleanability	SILKO-test (Chapter 4.2)	0 - 1 Poor	2 - 3 Moderate	4 - 5 Good	5 Very good
Removability	SILKO-test (Chapter 4.3)	No criterion/ grading			

3.2 Pore filling impregnants

Property	Test method	Criterion and grading			
		+	++	+++	++++
Obligatory tests					
Water permeability	EN 1062-3	No grading, only criterion: w, kg/m^2 · h^{½}			
		< 0,1	-	-	
Water vapour permeability	EN ISO 7783-1, free film [1)] EN ISO 7783-2, film on a substrate [1)]	s_D, m			
		≤ 100	≤ 50	≤ 5	≤ 0.5
Chloride permeability	NT BUILD 515	Chloride content at depth 10-20 mm, % of reference			
		≤ 100	≤ 20	≤ 15	≤ 8
Adhesion [2)]	EN 1542	Adhesion strength, MPa [*)] ≥ 1.5 (1.0) [*)] The value in brackets is the lowest accepted value of any reading.			
Frost salt durability	EN 13687-2, 10 cycles EN 13687-1, 20 cycles	a) no bubbles, cracks or delamination b) Pull-off-test Application/Load — Average [N/mm^2] vertical — ≥ 0.8 (0.5)[a] horizontal without mechanical load — ≥ 1.0 (0.7)[a] horizontal with mechanical load — ≥ 1.5 (1.0)[a] [a] The value in brackets is the lowest accepted value of any reading.			
Penetration depth	EN 1504-2	Penetration depth, mm			
		≥ 2	≥ 5	≥ 10	≥ 15
Voluntary tests					
Carbonation prevention	NT BUILD 357, CO_2 % (Chapter 4.1)	Carbonation depth, % of reference			
		≤ 20	≤ 15	≤ 8	
Cleanability	SILKO-test (Chapter 4.2)	0 - 1 Poor	2 - 3 Moderate	4 Good	5 Very good
Removability	SILKO-test (Chapter 4.3)	No criterion/ grading			

1) Alternative tests 2) Systems that form a continuous film.

3.3 Coatings

Property	Test method	Criterion and grading			
		+	++	+++	++++
Obligatory tests					
Water permeability	EN 1062-3	No grading, only criterion: w, kg/m^2 · h^{½}			
		< 0.1	-	-	
Water vapour permeability	EN ISO 7783-1 (free film) [1)] EN ISO 7783-2 (film on a substrate) [1)]	s_D, m			
		≤ 100	≤ 50	≤ 5	
Chloride permeability	NT BUILD 515	Chloride content at depth 10-20 mm, % of reference			
		≤ 50	≤ 20	≤ 15	≤ 8
Carbon dioxide permeability	EN 1062-6	No grading, only criterion: s_D, m			
		> 50	-	-	
Adhesion	EN 1542	Adhesion strength, MPa Crack bridging coatings: ≥ 0.8 Others: ≥ 1.5			
Freeze thaw durability	EN 13687-3, 20 cycles	a) no bubbles, cracks or delamination b) Pull-off-test Average [N/mm^2] Crack-bridging or flexible systems / Rigid systems[a] without trafficking: ≥ 0.8 (0.5)[b] / ≥ 1.0 (0.7)[b] with trafficking: ≥ 1.5 (1.0)[b] / ≥ 2.0 (1.5)[b] [a] Rigid coatings are coatings with shore D ≥ 60 according to EN ISO 868. [b] The value in brackets is the lowest accepted value of any reading.			
Dry film thickness	SILKO-test (Chapter 4.4)	Polymer coatings: ≥ 300 µm Cement based coatings: ≥ 2000 µm			
Voluntary tests					
Crack bridging ability	EN 1062-7, Method A, -30 °C	Crack width at failure, mm			
		≥ 0.3	≥ 0.6	≥ 1.0	
Removability	SILKO-test (Chapter 4.3)	Easily removable			
Cleanability	SILKO-test (Chapter 4.2)	0 - 1 Poor	2 - 3 Moderate	4 - 5 Good	5 Very good
Declared by manufacturer					
UV-resistance	EN 11507, 500 h	No sensory changes after the test			
Water resistance	SILKO-test (Chapter 4.5)	No irreversible sensory changes after the test			
Alkali resistance	SILKO-test (Chapter 4.6)	No irreversible sensory changes after the test			

1) Alternative tests

3.4 Anti-graffiti agents - Sacrificial

Property	Test method	Criterion and grading			
		+	++	+++	++++
Obligatory tests					
Product identification	IR (EN 1767) or TGA (EN ISO 11358)	No criterion			
Water permeability	EN 13580 [1]	Absorption rate, % of reference			
		< 15	≤ 10	≤ 5	
	EN 1062-3 [2]	No grading, only criterion: w, kg/m^2 · h^{½}			
		< 0.1	-	-	
Water vapour permeability					
Film forming systems	EN ISO 7783-1 (free film) [3]	s_D, m			
	EN ISO 7783-2 (film on a substrate) [3]	≤ 100	≤ 50	≤ 5	
Systems not forming a continuous film	EN 13579	Drying rate coefficient (Mean drying rate of treated test cubes/ Mean drying rate of untreated test cubes * 100), % Class I: > 30 Class II: > 10			
Cleanability	SILKO-test (Chapter 4.2)	0 - 1 Poor	2 - 3 Moderate	4 - 5 Good	5 Very good
Frost-salt durability [1]	EN 13581 [4]	The loss of mass of the impregnated specimen must occur at least 20 cycles later than that of the not impregnated specimen.			
	CEN/TS 12390-9 [4]	Scaling, % of reference			
		≤ 100	≤ 65	≤ 25	≤ 10
Freeze thaw durability [2]	EN 13687-3, 20 cycles [5]	a) no bubbles, cracks or delamination b) Pull-off-test: Average [N/mm^2] Crack-bridging or flexible systems / Rigid systems[a] without trafficking: ≥ 0.8 (0.5)[b] / ≥ 1.0 (0.7)[b] with trafficking: ≥ 1.5 (1.0)[b] / ≥ 2.0 (1.5)[b] [a] Rigid coatings are coatings with shore D ≥ 60 according to EN ISO 868. [b] The value in brackets is the lowest accepted value of any reading.			
	CEN/TS 12390-9 [5]	No visible defects			
Removability	Hot water pressure cleaning	The protective agent must detach from substrate			
Dry film thickness [2]	SILKO-test (Chapter 4.4)	No criterion			
Voluntary tests					
Chloride permeability	NT BUILD 515	Chloride content at depth 10-20 mm, % of reference			
		≤ 100	≤ 20	≤ 15	≤ 8
Carbonation prevention	NT BUILD 357 CO_2-pitoisuus 1 % (Chapter 4.1)	Carbonation depth, % of reference			
		≤ 100	≤ 60	≤ 20	
Declared by manufacturer					
UV-resistance	EN 11507, 500 h	No sensory changes after the test			

1) Systems not forming a continuous film
2) Systems that form a continuous film
3) Alternative tests.
4) Alternative tests.
5) Alternative tests.

4. SILKO-test methods

4.1 Effect of the protective agent on carbonation rate

4.1.1 Concrete specimens to be treated with the protective agent and their curing

The test is carried out using concrete prisms measuring, 40 x 40 x 160 mm³, with 2 prisms per each protective agent as well as 2 reference prisms per each series of tests.

The prisms are prepared of mortar MC(0,45) defined in EN 1766 with the maximum grain size of 8 mm. The specimens are water cured for 24 h after casting at (20 ± 2) °C, then demoulded and cured for a further 27 days at t = 20 ± 2 °C and RH = 95 ± 5%. Following this, the prisms are sandblasted and they are dried for 24 hours in a vacuum oven with a temperature of 30 ± 2 °C. Vacuum suction must be in operation for 8 hours from the start of the drying process.

The prisms are kept in plastic bags until they are treated with the protective agent at the age of about 42 days.

4.1.2 Application of the protective agent and its curing

The protective agent is applied to all sides of the prisms and cured in accordance with the manufacturer's instructions.

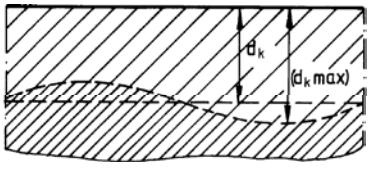
4.1.3 Test procedure /1/

The test is carried out according to NT BUILD 357 with the exception that the CO_2 content of the test chamber is 1 %.

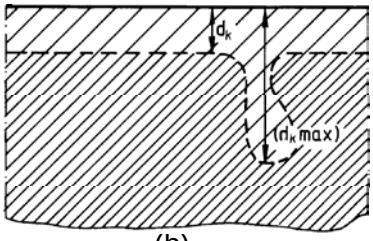
The test consists of storing the treated prisms and non-treated reference prisms in air with a carbon dioxide content of 3...5% for a period of 3 months. The storage temperature is 20 ± 2 °C and relative humidity 65 ± 5%.

Carbonation is monitored during the test by cutting one treated prism and one reference prism at one third of its length following a carbon dioxide treatment of 0, 0.5, 1, 2 and 3 months, respectively, and by applying a phenolphthalein indicator to the exposed surface. The carbonation depth of the exposed surfaces is measured. The exposed surfaces can also be photographed.

If the carbonation front does not run as a straight line parallel to the surface, the depth of carbonation must be determined in the following way:



(a)



(b)

In the case of the carbonation front running as in Fig (a), a graphical average and the maximum are recorded. If the carbonation front runs parallel to the surface, apart from isolated deeper carbonated areas, as in Fig (b), then the maximum depth of carbonation must be given as well as the normal depth. In this case no average is to be calculated. Greater depths of carbonation in the corner areas of laboratory specimens, where carbon dioxide has penetrated from two sides at once, are to be ignored.

Accelerated carbonation of the prisms through the exposed surfaces is prevented by applying a suitable resin to these surfaces.

4.1.4 Test results

The ratio of the carbonation depth of the treated prisms to that of the non-treated reference prisms following a carbon dioxide treatment of 0, 0.5, 1, 2 and 3 months are presented as the test results. If so desired, the pictures may be accompanied by photographs showing the carbonated areas.

4.2 Cleanability

4.2.1 Concrete specimens to be treated with the protective agent

The test is carried out using ready-made sandblasted concrete paving slabs measuring 40 x 300 x 300 mm³, with 2 slabs per each protective agent and 2 non-treated reference slabs per each series of tests. The slabs are stored at least for 14 days before using at 20 ± 2°C and relative humidity 65 ± 5%.

4.2.2 Application of the protective agent and its curing

The protective agent is applied to the sandblasted surface of the concrete slabs and cured in accordance with the manufacturer's instructions.

4.2.3 Test procedure

The sandblasted surface of the treated slabs and non-treated reference slabs is divided into three sections. Graffities are drawn on one section using paint from a spray can, on one section using alkyd paint and on one section using a water-proof felt pen.

After the application of the graffities, the slabs are stored for 7 days at a relative humidity of 65 ± 5% and a temperature of 20 ± 2 °C, after which they are photographed and one slab per each protective agent and one reference slab is cleaned using (high-pressure) water cleaning (using hot water) and one using a cleaning agent and method recommended by the manufacturer of the protective agent.

After cleaning, a visual inspection of the slabs is carried out to evaluate how effectively the applied paint has been removed. The slabs are also photographed.

4.2.4 Test results

Test results are presented in the form of a numeric evaluation of how effectively the graffities were removed, accompanied by photographs taken after cleaning. The numeric value varies from 0 to 5. 0 means that the graffiti does not remove at all and 5 means that the graffiti removes totally. The values between 0 and 5 are determined according to the table below.

Average cleaning of the specimens	Difference of the average cleaning of the graffities compared to the reference					
	≥ 2			< 2		
	Estimated total cleanability		SILKO-rating	Estimated total cleanability		SILKO-rating
	Verbal	Numeric		Verbal	Numeric	
5	Very good	5	++++	Very good	5	++++
4	Good	4	+++	Poor	1	+
3	Moderate	3	++	Poor	1	+
2	Moderate	2	++	Poor	1	+
1	Poor	1	+	Poor	1	+
0	Poor	0	+	Poor	0	+

4.3 Removability of a protective agent

4.3.1 Concrete specimen to be treated with the protective agent and its curing

A sandblasted prefabricated concrete paving slab, 40 x 300 x 300 mm³, is used as test specimen.

4.3.2 Application of the protective agent and its curing

The protective agent is applied on the sandblasted surface of the slab according the instructions of the manufacturer.

4.3.3 Test procedure

The slabs are cured at 20 ± 2 °C at 65 ± 5% relative humidity for at least 7 days.

The protective agent is removed according to the instructions given by the manufacturer.

If the manufacture does not recommend any removal method, the protective agent is removed by sandblasting from an area of 100 x 100 mm². The sandblasting is carried out using glass balls, 6 bar pressure, ø 8 mm nozzle, from 40 mm distance, perpendicular to the surface. Sandblasting is carried out along 10 mm wide stripes. The nozzle is moved back and forth at the rate of 200 mm/s.

The removability of the protective agent is estimated paying attention to the difficulty of removing and remnants of the protective agent.

4.3.4 Test results

The estimation of removability as well as the amount of protective agent remnants are given as test results.

4.4 Dry film thickness of the protective agent

4.4.1 Specimens

The dry film thickness of the protective agent on the test specimens used for any test(s) is measured.

4.4.2 Test procedure

A test specimen is broken. The thickness of the protective agent is measured on the fracture surface using a microscope with a magnification of at least 50 x. The length of the surface to be measured is at least 100 mm.

4.4.3 Test results

The minimum, maximum and average thicknesses of the protective agent are given as test results.

4.5 Water resistance

4.5.1 Test specimens

Test specimens are concrete prisms, 160 x 40 x 40 mm^3, the number of which is 2 per each protective agent.

The prisms are prepared of mortar MC(0,45) defined in EN 1766 with the maximum grain size of 8 mm. The specimens are water cured for 24 h after casting at (20 ± 2) °C, then demoulded and cured for a further 27 days at t = 20 ± 2 °C and RH = 95 ± 5%. Following this th prisms are cured for at least 14 days at t = 20 ± 2 °C and RH = 65 ± 5%.

4.5.2 Application of the protective agent and its curing

Three long sides of the prisms cast against the form are pre-treated and treated according the manufacturer´s instructions.

The treated specimens are cured according to the manufacturer´s instructions. In addition to the before mentioned special curing the specimens are stored at t = 20 ± 2 °C and RH = 65 ± 5% for a period of 7 days.

4.5.3 Test procedure

The prisms are placed in water at room temperature in such a way that the long side is downwards. The volume of the solution is at least four times that of the total volume of the specimens. The solution is changed in two week intervals. The duration of the test is 6 weeks after which the specimens are removed at t = 20 ± 2 °C and RH = 65 ± 5% for 7 days.

The condition of the protective agent is evaluated visually before and after the test.

4.5.4 Test result

Changes of the protective agents are reported as test results.

4.6 Alkali resistance

4.6.1 Concrete specimens to be treated with the protective agent and their curing

Test specimens are concrete prisms, 160 x 40 x 40 mm^3, the number of which is 2 per each protective agent.

The prisms are prepared of mortar MC(0,45) defined in EN 1766 with the maximum grain size of 8 mm. The specimens are water cured for 24 h after casting at (20 ± 2) °C, then demoulded and cured for a further 27 days at t = 20 ± 2 °C and RH = 95 ± 5%. Following this th prisms are cured for at least 14 days at t = 20 ± 2 °C and RH = 65 ± 5%.

4.6.2 Application of the protective agent and its curing

Three long sides of the prisms cast against the form are pre-treated and treated according the manufacturer´s instructions.

The treated specimens are cured according to the manufacturer´s instructions. In addition to the before mentioned special curing, the specimens are stored at t = 20 ± 2 °C and RH = 65 ± 5% for a period of 7 days.

4.6.3 Test procedure

The prisms are placed in saturated $Ca(OH)_2$-solution at room temperature in such a way that the long side is downwards. The volume of the solution is at least four times that of the total volume of the specimens. The solution is changed in two week intervals. The duration of the test is 6 weeks after which the specimens are removed at t = 20 ± 2 °C and RH = 65 ± 5% for 7 days.

The condition of the protective agent is evaluated visually before and after the test.

4.6.4 Test result

Changes of the protective agents are reported as test results.

5. References

1. NT BUILD 515. Edition 1. Approved 2015 – 12. 5 s. http://www.nordtest.info/images/documents/nt-methods/building/NT_BUILD_515_hydrophobic_impregnations_for_concrete.pdf