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CUSTOMER REPORT

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Injection and sealing compounds of cracks in concrete – SILKO test program 2020

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Project name TAITO 2020	Project number/Short name 127294/TAITO2020
<p>Summary</p> <p>This is an unofficial translation of the Finnish customer report. In case of interpretation disputes the Finnish report.</p> <p>This test program is an updated version of the test program VTT-CR-01205-16.</p> <p>These SILKO test instructions are used to examine the suitability of injection and sealing compounds of cracks in concrete engineering structures of the orderer (developer). The suitable materials are published in SILKO-directions which are available on the web pages, www.liikennevirasto.fi/palveluntuottajat/ohjelutelo.</p> <p>The test program of injection compounds is based on the European standard EN 1504-5 (2004). In addition the colour of the material is evaluated. 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 show that the material has got some special property suitable for special cases.</p> <p>The injection agent must have a CE marking, declaration of performance according to EN 1504-5 and AVCP class 2+.</p> <p>EN 1504-5 does not cover sealing materials the test programs of which are given in this report.</p> <p>In addition to the test programs also grading of the test results are given in this report.</p>	
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1. Introduction

These instructions are used to examine the suitability of injection and sealing compounds of cracks in concrete engineering structures of the orderer (developer). Materials that on the bases of the results of the tests of this test program fulfil the orderer's requirements can be used in the repair projects of the engineering structures of the orderer. The suitable materials are published in SILKO-directions which are available on the web pages www.liikennevirasto.fi/palveluntuottajat/ohjeluetelo.

The test program is based on the European standard EN 1504-5 (2004). In addition the colour of the material is evaluated. Part of the tests are obligatory and part are voluntary. On the bases of the results of the obligatory tests the orderer decides about the applicability of the materials in orderer's projects. The voluntary tests are carried out to show that the material has got some special property suitable for special cases.

The injection compound must have a CE marking, declaration of performance according to EN 1504-5 and AVCP class 2+. EN 1504-5 does not cover sealing materials. Here the test programs for both the sealing compounds for temporary sealing of cracks for injection work and permanent sealing of cracks by filling them by penetrating compounds are given.

In addition to the test programs also grading of the test results are given in this report.

Test methods other than those according to standards are described in sections 5–8.

2. Injection compounds

The SILKO test programs of injection compounds are given in Tables 1–3.

Table 1. Injection agents for force transmitting filling of cracks (F)

P = Injection product formulated with reactive polymer binder.

H = Injection product formulated with hydraulic binder.

Property	Test method	Grading
Obligatory tests		
Adhesion (H,P)	EN 12618-2 Concrete MC(0,45)	> 2 N/mm ² (H) Cohesive failure in the substrate (P) Injection products only intended for filling voids and interstices > 0.6 N/mm ² (H)
Volumetric shrinkage (P) ^a	EN 12617-2	< 3%
Non-volatile matter (P) ^a	EN ISO 3251	> 95%
Bleeding (H)	EN 445/4.5	Bleeding < 1% of the initial volume after 3 h
Volume change (H)	EN 445/4.5	- 1% < volume change < + 5% of the initial volume
Glass transition temperature (P)	EN 12614	> 40 °C
Chloride content (H)	EN 196-21	< 0.2%
Viscosity (P)	EN ISO 3219	No grading
Time of efflux (H)	EN 14117	No grading
Setting time (H)	EN 196-3 Three conditioning and test temperatures: 21 °C, minimum and maximum temperatures recommended	No grading

Property	Test method	Grading
	by the manufacturer,, with a tolerance of ± 2 °C	
Tensile strength development for polymers (P)	EN 1543 Three conditioning and test temperatures: 21 °C, minimum and maximum temperatures recommended by the manufacturer,, with a tolerance of ± 2 °C	Tensile strength > 3 N/mm ² within 72 h at the minimum use temperature, or within 10 h at the minimum use temperature by daily crack movements higher than 10% or 0.03 mm (the lowest value is taken into account).
Workable time (H, P) Period of time the mixed injection product remains workable in the batch quantities used and at the limit of conditions that the product is fit for the purpose of use.	EN ISO 9514 Three conditioning and test temperatures: 21 °C, minimum and maximum temperatures recommended by the manufacturer,, with a tolerance of ± 2 °C. Sample: 1 000 ml, instead of 300 ml. (H) Pot life is the period of time taken by the freshly mixed product to: <ul style="list-style-type: none"> · increase in temperature by 15 °C, for injection products formulated with reactive polymer binder (or the maximum temperature increase if less than 15 °C) (P) · to reach a recorded lowering of the filtration stability (H) Workable time is 70% of the pot life if no other recommendations are given by the manufacturer	No grading
Injectability into dry medium (H, P) ^b		
Crack widths: 0,1 mm–0,2 mm–0,3 mm: determination of injectability and splitting test (H, P)	EN 1771	Injectability class < 4 min (high injectability) wk = 0.1 mm < 8 min (at least feasible) wk = 0.2 mm and wk = 0.3 mm Splitting test > 7 N/mm ² (P) > 3 N/mm ² (H) wk = crack width
Crack widths: 0,5 mm–0,8 mm or where EN 1771 is not suitable: adhesion by tensile bond strength (H, P)	EN 12618-2 (concrete MC(0,45)) For crack widths 0.3 mm–0.5 mm and 0.8 mm, inert flexible plastic spacers of respectively 0.3 mm–0.5 mm and 0.8 mm width shall be used	Percentage of the crack filled > 90% Adhesion requirements fulfilled
Injectability into non-dry medium (H, P) ^b		
Crack widths: 0.1 mm–0.2 mm–0.3 mm: determination of injectability and splitting test (H, P)	EN1771	Injectability class wk = 0.1: high injectability (< 4 min) wk = 0.2 and 0.3: at least feasible (< 8 min) Splitting test > 7 N/mm ² (P) > 3 N/mm ² (H) wk = halkeaman leveys
Crack widths: 0.5 mm–0.8 mm or where EN 1771 is not suitable : adhesion by tensile bond strength (H, P)	EN 12618-2 (concrete MC(0,45)) For crack widths 0.3 mm–0.5 mm and 0,8 mm, inert flexible plastic spacers of respectively 0.3 mm–0.5 mm and 0,8 mm width shall be used	Percentage of the crack filled > 90% Adhesion requirements fulfilled
Colour (H, P)	Chapter 5 of this test programme	No grading
Adhesion by tensile bond strength after thermal and wet-drying cycles (H, P)	EN 12618-2 (concrete MC(0,45))	Cohesive failure in the concrete (P) Reduction in tensile bond strength less than 30% of the initial values (H).

Property	Test method	Grading
Voluntary tests		
Slant shear strength (P, H) Dry or wet crack	EN 12618-3	Monolithic failure (similar pattern of cracking to the control prisms)
Hardening under dynamic loading (P)	Chapter 9 of this test programme	Cohesive failure in the concrete

^a Alternative tests

^b At least one of the tests must be carried out.

Table 2. Injection compounds for ductile filling of cracks, (D)

P = Injection product formulated with reactive polymer binder.

Property	Test method	Grading
Obligatory tests		
Adhesion and elongation capacity of ductile injection products (P)	EN 12618-1	Adhesion: No grading Elongation: > 10%
Injectability into dry medium (P) ^a		
Crack widths: 0.1 mm–0.2 mm–0.3 mm: determination of injectability (P)	EN 1771	Injectability class < 4 min (high injectability) $w_k = 0.1$ mm $w_k = 0.2$ mm and $w_k = 0.3$ mm at least feasible < 8 min (at least feasible) $w_k = 0.2$ mm and $w_k = 0.3$ mm $w_k =$ crack width
Crack widths 0.5 mm–0.8 mm or where EN 1771 is not suitable	Injection between concrete tiles EN 12618-2:2004, chapters 4.3–4.6 (concrete MC(0,45)) For crack widths 0.3 mm–0.5 mm and 0.8 mm, inert flexible plastic spacers of respectively 0.3 mm–0.5 mm and 0.8 mm width shall be used.	Percentage of the crack filled > 90%
Injectability into non-dry medium (P) ^a		
Crack widths: 0.1 mm–0.2 mm–0.3 mm: determination of injectability (P)	EN 1771	Injectability class < 4 min (high injectability) $w_k = 0.1$ mm < 8 min (at least feasible) $w_k = 0.2$ mm and $w_k = 0.3$ mm $w_k =$ crack width
Crack widths 0.5 mm–0.8 mm or where EN 1771 is not suitable	Injection between concrete tiles EN 12618-2:2004, chapters 4.3–4.6 (concrete MC(0,45)) For crack widths 0.3 mm–0.5 mm and 0.8 mm, inert flexible plastic spacers of respectively 0.3 mm–0.5 mm and 0.8 mm width shall be used.	Percentage of the crack filled > 90%
Viscosity (P)	EN ISO 3219	No grading
Compatibility with concrete (P)	EN 12637-1	No failure by compressive testing Lost deformation work < 20%
Colour (P)	Chapter 5 of this test programme	No grading
Workable time (P)	EN ISO 9514 Three conditioning and test temperatures: 21 °C, minimum and maximum temperatures recommended by the manufacturer,, with a tolerance of ± 2 °C. Pot life is the period of time taken by the freshly mixed product to increase in temperature by 15 °C (or the maximum temperature increase if less than 15 °C).	No grading

Property	Test method	Grading
	Workable time is the period of time the mixed injection product remains workable in the batch quantities used and at the limit of conditions that the product is fit for the purpose of use. Workable time is 70% of pot life if no other recommendations are given by the manufacturer	
Voluntary tests		
Watertightness (P)	EN 14068	Watertight at 200 000 Pa Special applications: Watertight at 700 000 Pa
Glass transition temperature (P)	EN 12614	No grading
Expansion ratio and evolution (P)	EN 14406	No grading
Effect on polymeric inserts (P)	EN 12637-3	After 70 days, the changes in elongation shall be lower than 20% of the initial value
Adhesion and elongation after thermal and wet-drying cycles. (P)	EN 12618-1 and EN 13687-3 The specimens specified in EN 12618-1 shall be submitted to 24 thermal and wet-drying cycles according to EN 13687-3, 7.1 and 7.2. The adhesion and elongation capacity shall then be measured as specified in EN 12618-1.	Adhesion: loss of adhesion lower than 20% of the initial value Elongation: > 10%
Watertightness (P) after elongation	EN 14068	After elongation (5%, 10% or declared by the manufacturer) watertight at 100 000 Pa

^a At least one of the tests must be carried out.

Table 3. Injection compounds for swelling fitted filling of cracks (S).

P = Injection product formulated with reactive polymer binder.

Property	Test method	Grading
Obligatory tests		
Viscosity (P)	EN ISO 3219 Where EN ISO 3219 is not suitable, EN 12618-2 shall be applicable. For crack widths 0.3 mm–0.5 mm and 0.8 mm, inert plastic spacers of respectively 0.3 mm–0.5 mm and 0.8 mm width shall be used.	$\leq 60 \text{ m Pa} \cdot \text{s}$ Percentage of the crack filled > 95
Expansion ratio and evolution by water storage Weight changes by air drying and water storage (P)	EN 14498	No grading
Watertightness (P)	EN 14068 The test method described in EN 14068 shall be completed by 500 cycles of pressure modifications, each cycle being constituted as follows: 15 min at 75% of the maximum pressure – 15 min at 25% of the maximum pressure. After application of the maximum declared pressure for 7 days, as provided in EN 14068, the pressure shall be	Watertight at 200 000 Pa Special applications: Watertight at 700 000 Pa

Property	Test method	Grading
	lowered to 50% of the maximum declared pressure, maintained 2 h at this pressure, before beginning the cycles.	
Workable time (P)	<p>EN ISO 9514</p> <p>The test shall be performed at three conditioning and test temperatures: 21 °C and the minimum and maximum use temperatures recommended by the manufacturer, with a tolerance of ± 2 °C.</p> <p>Pot life is the period of time taken by the freshly mixed product to increase in temperature by 15 °C (or the maximum temperature increase if less than 15 °C).</p> <p>Workable time is the period of time the mixed injection product remains workable in the batch quantities used and at the limit of conditions that the product is fit for the purpose of use.</p> <p>Workable time is 70% of pot life if no other recommendations are given by the manufacturer</p>	No grading
Sensitivity to water: expansion ratio caused by water storage - Covered by: Volume – and weight changes by air drying and water storage (P)	EN 14498 (conditioning regime A))	The expansion ratio shall reach a constant level during the water immersion.
Sensitivity to wet-drying cycles - Covered by: Volume – and weight changes by air drying and water storage (P)	EN 14498 (Storing according to method B)	After the wet – drying cycles, there shall be no change to the expansion ratio after water immersion.
Colour (P)	Chapter 5 of this test programme	No grading
Freezing point (P) a	EN ISO 11357-3	No grading
Compatibility with concrete (P)	<p>The test is performed on specimens according to EN 12637-1, 6.2 and 7.3.1.</p> <p>Sample: 6 specimens, each of 15 mm thickness.</p> <p>Conditioning: 3 specimens shall be conditioned in tap water and 3 specimens shall be conditioned in KOH 1M solution.</p> <p>The strength properties are measured by applying a compressive load with a speed of 100 mm/min on the specimen with a stamp \varnothing 20 mm provided by a conical head (angle 60°). The load/deformation curve is reported.</p>	The strength properties compared to the water immersed specimens shall not differ by more than 20%.
Voluntary tests		
Corrosion behaviour (P)	Orderer defines the test method case-specifically.	Shall not contain any substance in quantities which could cause corrosion of steel reinforcement
Effect on polymeric inserts	EN 12637-3	After 70 days, the changes in elongation shall be lower than 20% of the initial value

^a If a freezing point is showed by DSC analysis, the mechanical properties are determined in function of the temperature by compression testing in following conditions:

- cylindrical stamp of diameter: 50 mm;
- height of the sample: 35 mm;
- diameter of the sample: 100 mm;
- speed: 50 mm/min.

3. Sealing compounds for permanent crack filling

The test programme and grading of the test results of sealing compounds are given in Tables 4 and 5. There are no voluntary SILKO tests for sealing compounds. Table 4 concerns sealing compounds formulated with reactive polymer binder. Table 5 concerns sealing compounds formulated with hydraulic binder.

Table 4. Test programme and grading of test results of crack filling permanent sealing compounds formulated with reactive polymer binder.

Property	Test method	Grading
Obligatory tests		
Identification	Infra red analysis, (IR) EN 1767	No grading
Viscosity	EN ISO 3219 Viscosity shall be measured 5 min after mixing of the product has been completed. The separate of the product shall be maintained at a constant temperature of (21 ± 2) °C before mixing. The temperature of the freshly mixed product shall be measured and recorded before the viscosity is measured. For products that harden in less than 5 min viscosity shall be measured on unmixed components. /1/	No grading
Pot life	EN ISO 9514 The test shall be performed at three conditioning and test temperatures: 21 °C and the minimum and maximum use temperatures recommended by the manufacturer, with a tolerance of ± 2 °C. /1/	No grading
Colour	Chapter 5 of this test programme	No grading
Effect on the appearance of concrete	Chapter 5 of this test programme	No grading
Penetration	Chapter 6 of this test programme	≥ 30% of the crack surface is filled
Voluntary test		
Adhesion by slant shear strength	NT BUILD 350 Dry and/or wet crack	Grading scale: + < 50% ++ 50–100% +++ > 100% of the strength of the control prism

Table 5. Test programme and grading of test results of of crack filling permanent sealing compounds formulated with hydraulic binder.

Property	Test method	Grading
Obligatory tests		
Identification	Thermo-gravimetric determination according to EN ISO 11358	No grading

Property	Test method	Grading
Time of efflux	EN 14117 Viscosity shall be measured 5 min after mixing of the product has been completed. /1/	No grading
Setting time	EN 196-3	No grading
Colour	Chapter 5 of this test programme	No grading
Effect on the appearance of concrete	Chapter 5 of this test programme	No grading
Penetration	Chapter 6 of this test programme	≥ 30% of the crack surface is filled
Voluntary tests		
Adhesion by slant shear strength	NT BUILD 350 Dry and/or wet crack	Grading scale: + < 50% ++ 50–100% +++ > 100% of the strength of the control prism

4. Sealing compounds for temporary sealing of cracks for injection

The test programme and grading of test results are given in Tables 6 and 7. Table 6 concerns sealing compounds formulated with reactive polymer binder. Table 7 concerns sealing compounds formulated with hydraulic binder. There are no voluntary tests for sealing compounds.

Table 6. Test programme and grading of test results of temporary sealing compounds formulated with reactive polymer binder.

Property	Test method	Grading
Identification	Infra red analysis, (IR) EN 1767	No grading
Viscosity	EN ISO 3219 Viscosity shall be measured 5 min after mixing of the product has been completed. The separate components of the product shall be maintained at a constant temperature of (21 ± 2) °C before mixing. The temperature of the freshly mixed product shall be measured and recorded before the viscosity is measured. For products that harden in less than 5 min viscosity shall be measured on unmixed components. /1/	No grading
Pot life	EN ISO 9514 The test shall be performed at three conditioning and test temperatures: 21 °C and the minimum and maximum use temperatures recommended by the manufacturer, with a tolerance of ± 2 °C. /1/	No grading
Adhesion	EN 1542	≥ 0.4 N/mm ²
Colour	Chapter 5 of this test programme	No grading
Effect on the appearance of concrete	Chapter 5 of this test programme (dry and wet test specimen)	No grading
Spreadability	Evaluated in connection with the preparation of the test specimens for other tests (dry and wet test specimen)	Must not be too difficult to spread
Removability	Chapter 8 of this test programme (dry and wet test specimen)	No grading

Table 7. Test programme and grading f test results of temporary sealing compounds formulated with hydraulic binder.

Property	Test method	Grading
Identification	Thermo-gravimetric determination according to EN ISO 11358)	No grading
Time of efflux	EN 14117 Viscosity shall be measured 5 min after mixing of the product has been completed. /1/	No grading
Setting time	EN 196-3	No grading
Adhesion	EN 1542	$\geq 0.4 \text{ N/mm}^2$
Colour	Chapter 5 of this test programme	No grading
Effect on the appearance of concrete	Chapter 5 of this test programme (dry and wet test specimen)	No grading
Spreadability	Evaluated in connection with the preparation of the test specimens for other tests (dry and wet test specimen)	Must not be too difficult to spread
Removability	Chapter 8 of this test programme (dry and wet test specimen)	No grading

5. Colour and effect on the appearance of concrete

The colour of hardened injection compound placed in a transparent cup is evaluated visually.

The effect of a permanent crack filling sealing compound on the appearance of concrete is evaluated visually on concrete specimens with the compound applied on their surface. The effect on the appearance of concrete is evaluated to dry and wet concrete specimens. It is recommended to use Chapter 8 (Removability) specimens in this test.

The effect of a temporary sealing compound used for sealing cracks during injection on the appearance of concrete is evaluated visually on concrete specimens with the compound applied on their surface and removed after hardening.

Photographs and verbal visual evaluation are given as test results.

6. Penetration depth

6.1 Principle

The penetration depth of a permanent crack filling sealing compound into a concrete crack with known width is measured.

6.2 Test specimens and their pre treatment

The test specimens are two concrete beams, $100 \times 100 \times 500 \text{ mm}^3$.

For 7 days after casting the beams are stored in water after which they are stored at 95–100% relative humidity at $+20 \pm 2 \text{ }^\circ\text{C}$ for 21 days. At the age of 28 days the beams are bended to failure. One of the broken beams is removed into $65 \pm 5\%$ relative humidity and one into tap water at $+20 \pm 2 \text{ }^\circ\text{C}$ for 14 days.

6.3 Test procedure

Free water is removed from the fracture surface. The ends of the beams are placed in horizontal position with their fracture surfaces against each other in such a way that a crack with a width of 0.2 mm is formed. The crack is sealed with the crack filling sealing compound from the upper surface of the beam by tapping with a brush.

After the hardening of the sealing compound it is observed visually whether the compound seals the whole crack or not. The beams are again bended into failure. The penetration depth of a continuous layer of the sealing compound and the area the compound covers of the crack surface are measured.

6.4 Test results

Whether the sealing compound seals the whole crack or not, the average penetration depth and the minimum and the maximum of it and the relative portion of the crack area that is filled with the crack filling sealing compound at both humidity conditions are given as test results.

7. Spreadability

The spreadability of the temporary sealing compound is evaluated in connection with the preparation of the dry and wet test specimens for other tests. It is recommended to use Chapter 8 (Removability) specimens in this test.

8. Removability

8.1 Principle

The effort needed to remove the temporary sealing compound from the concrete surface, the damaging of the concrete substrate when the sealing compound is being removed and the effect of the application and removal of the sealing compound on the outlooks of the concrete surface are evaluated.

8.2 Test specimens and their pre treatment

Two concrete paving slabs are used as test specimens (dry and wet). Dry slab is stored for 14 days at $65 \pm 5\%$ relative humidity and wet slab in water at $+20 \pm 2$ °C.

8.3 Test procedure

Free water is removed from the surface of the slab stored in water. Approximately 40 mm wide and 250 mm long stripe of the temporary sealing compound is applied on both slabs. The thickness of the applied layer is according to the directions of the product. The slab stored at $65 \pm 5\%$ relative humidity is returned there and the slab stored in water is removed into 95–100% relative humidity at +20 °C.

After 3 days the colour of the sealing compound is evaluated and the slabs are photographed. The sealing compound is removed from the slab surfaces using applicable tools. The

removability is evaluated. In the end the effect of the removed sealing compound on the appearance of the concrete substrate is evaluated and the slabs are photographed.

8.4 Test results

The evaluation of the removability of the sealing compound and the effect of the removed sealing compound on the appearance of the concrete substrate are given as test results. In addition photographs taken of the slabs before and after the removal of the sealing compound are presented.

9. Hardening under dynamic loading

9.1 Principle

Concrete beams cut in two are glued together with the injection compound, loaded with dynamic fatigue load during the hardening of the injection compound. After the hardening of the injection compound the beams are loaded to failure.

9.2 Test specimens and their pre treatment

Two concrete beams, 100 x 100 x 500 mm³, prepared of concrete C(0,40) defined in EN 1766 are used as test specimens.

For the first 24 hours after casting the specimens are cured in moulds covered with plastic sheets. After demoulding the specimens are water cured for 7 d at $t = 20 \pm 2$ °C after which they are cured for a further 21 days at $t = 20 \pm 2$ °C and $RH = 95 \pm 5\%$. At the age of 28 d the beams are cut in two at the centre point in 60 degrees inclination as shown in Figure 1. The cut surfaces are cleaned and the halves of the beams are cured at least 7 d at $t = 20 \pm 2$ °C and $RH = 65 \pm 5\%$ before gluing of the beam halves together with the injection compound.

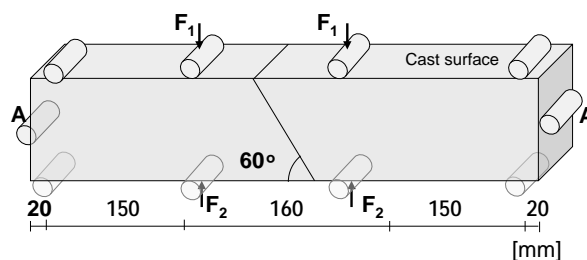


Figure 1. Loading arrangement of the beam.

The beams are tested one by one till the end of dynamic testing. The halves of the beams are glued together with the injection compound. For instance duct tape may be used to prevent the running off of the injection compound from the gap.

9.3 Test procedure

The loading arrangement of the is shown in Figure 1. Sideways bending of the beam and horizontal movement of the halves are prevented (supports A in Figure 1). The loading is started 10 ± 2 min after the beginning of gluing. Loading will go on for as long as the injection

compound is hardened or for 15. min whichever is longer. Loading is done at the points marked as F_1 and F_2 in Figure 1 in such a way that the maximum movement is 0.1 mm and the loading frequency is 1 Hz.

After dynamic fatigue loading and hardening of the injection compound the beam is loaded to failure using loads F_1 and by removing loads F_2 . shown in Figure 1.

9.4 Test results

The failure modes of both beams are given as test results.

References

1. EN 1504-5. Products and systems for the protection and repair of concrete structures. Definitions, requirements, quality control and evaluation of conformity. Part 5: Concrete injection. 2005. 36 p.