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CALCINED LAYER SILICATE
BASED TYPE II ADDITION

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This European Assessment Document (EAD) has been developed taking into account up-to-date technical and scientific knowledge at the time of issue and is published in accordance with the relevant provisions of Regulation (EU) 305/2011 as a basis for the preparation and issuing of European Technical Assessments (ETA).

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1 SCOPE OF THE EAD

1.1 Description of the construction product

The "calcined layer silicate based type II addition" is a finely divided powder. The calcined layer silicate is produced of layer silicate by a specific thermal and mechanical process. It consists essentially of SiO₂ and Al₂O₃.

The content of reactive SiO₂, as defined and described in EN 197-1¹, amounts to at least 25 % by mass acc. to EN 450-1.

The product can be supplied as powder or as slurry. The slurry is a pH-regulated liquid suspension of "calcined layer silicate based type II addition" in water.

The product is not covered by a harmonised European standard (hEN).

Concerning product packaging, transport, storage, maintenance, replacement and repair it is the responsibility of the manufacturer to undertake the appropriate measures and to advise his clients on the transport, storage, maintenance, replacement and repair of the product as he considers necessary.

It is assumed that the product will be installed according to the manufacturer's instructions or (in absence of such instructions) according to the usual practice of the building professionals.

Relevant manufacturer's stipulations having influence on the performance of the product covered by this European Assessment Document shall be considered for the determination of the performance and detailed in the ETA.

1.2 Information on the intended use(s) of the construction product

1.2.1 Intended use(s)

The "calcined layer silicate based type II addition" is a type II addition (pozzolanic) for production of concrete, including in particular cast-in-situ or prefabricated structural concrete conforming to European standard EN 206.

It is also intended to use "calcined layer silicate based type II addition" in mortars and grouts.

From EN 206 all strength classes and consistency classes apply. All exposure classes are included. "Calcined layer silicate based type II addition" is intended to be used in combination with Portland cement (CEM I) or Portland-composite cement (CEM II/A-S, CEM II/B-S; CEM II/A-LL) or blast-furnace cement (CEM III/A).

The recommended maximum dosage of "calcined layer silicate based type II addition" is 11 % by cement mass.

1.2.2 Working life/Durability

The assessment methods included or referred to in this EAD have been written based on the manufacturer's request to take into account a working life of the "calcined layer silicate based type II addition" for the intended use of 50 years when installed in the works provided that the concrete incorporating the "calcined layer silicate based type II addition" is subject to appropriate installation (see 1.1). These provisions are based upon the current state of the art and the available knowledge and experience.

¹ All undated references to standards or to EADs in this Chapter are to be understood as references to the dated versions listed in clause 4.

When assessing the product, the intended use as foreseen by the manufacturer shall be taken into account. The real working life may be, in normal use conditions, considerably longer without major degradation affecting the basic requirements for works².

The indications given as to the working life of the construction product cannot be interpreted as a guarantee neither given by the product manufacturer or his representative nor by EOTA when drafting this EAD nor by the Technical Assessment Body issuing an ETA based on this EAD, but are regarded only as a means for expressing the expected economically reasonable working life of the product.

² The real working life of a product incorporated in a specific works depends on the environmental conditions to which that works is subject, as well as on the particular conditions of the design, execution, use and maintenance of that works. Therefore, it cannot be excluded that in certain cases the real working life of the product may also be shorter than referred to above.

2 ESSENTIAL CHARACTERISTICS AND RELEVANT ASSESSMENT METHODS AND CRITERIA

2.1 Essential characteristics of the product

Table 1 shows how the performance of the "calcined layer silicate based type II addition" is assessed in relation to the essential characteristics.

Assessment acc. to clauses 2.2.1 to 2.2.13 is done on 5 samples taken from a current production of the product (powder or slurry). Determination of loss on ignition is only done on powder.

Additional assessment of a slurry acc. to clauses 2.2.14 to 2.2.17 is done on 3 samples.

The "calcined layer silicate based type II addition"-sample with the lowest relative compressive strength (see clause 2.4.13) is used for the assessment acc. to clauses 2.2.18 to 2.2.24.

Table 1 Essential characteristics of the product and methods and criteria for assessing the performance of the product in relation to those essential characteristics

No	Essential characteristic	Assessment method	Type of expression of product performance
Basic Works Requirement 1: Mechanical resistance and stability			
1	Sulfate content	2.2.1	Level
2	Silicon dioxide content	2.2.2	Level
3	Aluminium oxide content	2.2.3	Level
4	Chloride content	2.2.4	Level
5	Loss on ignition (only powder)	2.2.5	Level
6	Total content of alkalis	2.2.6	Level
7	Content of soluble alkalis	2.2.7	Level
8	Sieve residue on 200 µm sieve	2.2.8	Level
9	Specific surface	2.2.9	Level
10	Fineness	2.2.10	Level
11	Initial setting time	2.2.11	Description
12	Soundness	2.2.12	Description
13	Relative compressive strength (of mortar) at 28 days	2.2.13	Level
14	pH value of the slurry	2.2.14	Level
15	Density of the slurry	2.2.15	Level

No	Essential characteristic	Assessment method	Type of expression of product performance
16	Dry mass content of the slurry	2.2.16	Level
17	Stability of the slurry	2.2.17	Description
18	Analysis of the pore-solution	2.2.18	Description
19	Content of Ca(OH) ₂	2.2.19	Description
20	Compressive strength of concrete	2.2.20	Description
21	Carbonation of concrete	2.2.21	Description
22	Freeze-thaw resistance	2.2.22	Level
23	Resistance against chloride penetration	2.2.23	Description
24	Shrinkage	2.2.24	Description

2.2 Methods and criteria for assessing the performance of the product in relation to essential characteristics of the product

In the following clauses "shall be stated" means "shall be stated in the ETA".

Regarding the test methods according to EN 196-2 the reference test methods shall be used for the different characteristics according to clause 2.2.1 to 2.2.7 unless stated otherwise.

2.2.1 Sulfate content

The sulfate content, expressed as SO₃, is determined by the method described in EN 196-2.

The sulfate content shall be stated.

2.2.2 Silicon dioxide content

The content of silicon dioxide, expressed as SiO₂, is determined by the method described in EN 196-2.

The content of silicon dioxide shall be stated.

2.2.3 Aluminium dioxide content

The content of aluminium dioxide, expressed as Al₂O₃, is determined by the method described in EN 196-2.

The content of aluminium dioxide shall be stated.

2.2.4 Chloride content

The chloride content, expressed as Cl⁻, is determined by the method described in EN 196-2.

The chloride content is not higher than 0,10 % by mass acc. to EN 15167-1, table 1.

If the Cl^- content is higher than 0,10 % by mass, the upper limit value shall be stated.

2.2.5 Loss on ignition

The loss on ignition is determined by the method described in EN 196-2 but using an ignition time of 1 hour.

The loss on ignition shall be stated.

2.2.6 Total content of alkalis

The total content of alkalis is determined by the method described in EN 196-2 and calculated as Na_2O equivalent.

The total content of alkalis, calculated as Na_2O equivalent, shall be stated.

Different national provisions adopt different principles but in general only a very small proportion of alkalis in "calcined layer silicate based type II addition" are considered to contribute to alkali silica reaction, CEN Report CR 1901:1995.

For the content of soluble alkalis see clause 2.2.7.

2.2.7 Content of soluble alkalis

The content of soluble alkalis is determined by the method described in EN 196-2 except that the leaching is done in accordance with EN 1744-1, clause 7. The content of soluble alkalis is calculated as Na_2O (equivalent).

The content of soluble alkalis, calculated as Na_2O equivalent, shall be stated.

2.2.8 Sieve residue on 200 μm sieve

The sample (dried at (105 ± 5) °C till constant mass) is sieved according to EN 933-10 on a 200 μm sieve according to ISO 3310-1. Agglomerates, which cannot be crushed between one's fingers, and impurities are considered as sieve residue on the 200 μm sieve.

For the slurry the determination of sieving residue is carried out with wet sieving. Wet sieving shall be done according to EN 451-2, with the exception that the sieve size is 200 μm . The sieve residue on the 200 μm sieve is dried at (105 ± 5) °C till constant mass.

The sieve residue on the 200 μm sieve shall be stated.

2.2.9 Specific surface (BET method)

The specific surface is determined by nitrogen adsorption according to the method given in ISO 9277.

The specific surface shall be stated.

2.2.10 Fineness

The fineness of the addition is expressed as the mass proportion of the retained addition in percent when wet sieved on a 0,045 mm sieve and determined in accordance with EN 451-2.

The fineness of the addition shall be stated.

2.2.11 Initial setting time

The initial setting time is determined on a cement paste consisting of 10 % addition³ plus 90 % test cement (by mass) in accordance with EN 196-3.

The test cement shall be a Portland cement CEM I 42,5 R according to EN 197-1. The test cement shall fulfil the following (acc. to EN 13263-1):

- Tricalcium aluminate: 8 to 12 % by mass
- Alkalis (Na₂O eqv): 0,6 % to 1,2 % by mass
- Fineness: 300 m²/kg to 400 m²/kg

The initial setting time of the cement paste consisting of 10 % addition plus 90 % test cement shall be less than twice as long as the initial setting time of a 100 % (by mass) test cement paste acc. to EN 450-1, 5.3.5. Both initial setting times shall be stated.

2.2.12 Soundness

The soundness is determined by testing the expansion in accordance with EN 196-3.

The expansion of the cement paste in accordance with 2.2.11 is not higher than 10 mm acc. to EN 197-1, table 3.

2.2.13 Relative compressive strength (of mortar) at 28 days

The relative compressive strength is determined as the ratio (in percent) of the compressive strength of standard mortar bars, prepared with 90 % cement plus 10 % "calcined layer silicate based type II addition" (by mass of total binder), to the compressive strength of standard mortar bars prepared with 100 % test cement, tested at the same age.

Preparation of standard mortar bars and determination of the compressive strength is carried out in accordance with the method described in EN 196-1. The mortar containing "calcined layer silicate based type II addition" shall be mixed with an amount of superplasticizer (conforming to EN 934-2) so that the mortar has a consistency equivalent to the mortar prepared with 100 % test cement. The content and type of superplasticizer shall be given.

The consistence of the fresh mortar is determined by flow table method according to EN 1015-3.

The bulk density is determined according to EN 1015-6 and the air content of the fresh mortar is determined according to EN 1015-7.

For the tests 3 Portland cements (CEM I), 1 Portland-slag cement (CEM II/B-S) and 1 blast-furnace slag cement (CEM III/A) shall be used.

The selection of the cements shall fulfil the following:

- One CEM I 42,5 R, one CEM II/B-S 32,5 R with a blast-furnace slag content of around 30 % by mass and one CEM III/A 32,5 N with a blast-furnace content of around 60 % by mass shall be of the same production plant. Furthermore the used Portland cement clinker and blast-furnace slag of the three cements shall be identical,
- One CEM I 42,5 R shall fulfil the requirements in clause 2.2.11,
- One CEM I 42,5 N with Na₂O_{eqv} ≤ 0,60 % by mass shall be used.

³ The "calcined layer silicate based type II addition"-sample with the lowest relative compressive strength shall be taken, see clause 2.2.13.

The two CEM I 42,5 R shall have significantly different alkali contents as Na₂O (equivalent).

The relative compressive strength tested with CEM I acc. to 2.2.11 gives the "activity index" acc. to EN 13263-1. The relative compressive strength is at least 100 % when tested at 28 days.

2.2.14 pH value of the slurry

The pH value of the slurry is determined at a temperature of 20 °C in accordance with ISO 4316.

The pH value of the addition shall be stated. The stated value shall be the mean value of test results determined on 3 samples by assessment testing. Deviation of the pH value is tolerated when being within the range (± 1) acc. to EN 934-1, table 1, No. 6.

2.2.15 Density of the slurry

The density of the slurry is determined at a temperature of 20 °C in accordance with ISO 2811-1.

The density of the slurry shall be stated. The stated value shall be the mean value of test results determined on 3 samples by assessment testing. Deviation of the density is tolerated when being within the range ($\pm 0,02$) g/cm³ acc. to EN 934-1, table 1, No. 4.

2.2.16 Dry mass content of the slurry

The dry mass content of the slurry is determined by drying a representative sample of at least 5 g of slurry in a well ventilated oven at (105 ± 5) °C to constant mass. Constant mass is considered to be reached when successive weighing at minimal intervals of 1 hour during drying at (105 ± 5) °C do not differ by more than 0,2 %.

The dry mass content of the slurry shall be stated.

2.2.17 Stability of the slurry

The stability of the slurry is determined on "calcined layer silicate based type II addition"-slurry that was taken from at least 20 cm under the slurry surface of the container. A sample of the agitated slurry (1 litre-sample) should be taken and decanted in a cylinder. The hermetically sealed cylinder with the slurry is positioned for 90 days. After 7, 14, 28, 56 and 90 days the sedimentation tendency of the slurry shall be observed and the thickness of sediment, if any, shall be measured.

Any sedimentation tendency shall be recorded.

2.2.18 Analysis of the pore solution

The pore solution (OH⁻-Ionics by acid capacity (acc. to CEN/TS 15364) Ks 8,2 and Ks 4,3, K⁺, Na⁺, Ca⁺, pH value) of hardened cement paste made with and without addition³ is analysed by the test method given in Annex A after 7, 28 and 90 days.

The chemical composition of the pore-solution of hardened cement paste with addition and the chemical composition of the pore-solution of hardened cement paste without addition shall be stated (OH⁻-Ionics Ks 8,2 and Ks 4,3, K⁺, Na⁺, Ca⁺, pH value).

2.2.19 Content of Ca(OH)₂

The content of calcium hydroxide (Ca(OH)₂) of hardened cement paste made with and without addition³ is determined by the test method given in Annex B after 7, 28 and 90 days.

The content of Ca(OH)₂ of hardened cement paste with addition and the content of Ca(OH)₂ of hardened cement paste without addition shall be stated.

2.2.20 Compressive strength of concrete

The compressive strength of concrete made with and without addition is determined according to EN 12390-3 after 7, 28 and 90 days (3 test specimen/concrete mix for each test age).

After demoulding the concrete specimens made with and without addition are immersed in water until the age of 7 days. Afterwards they are stored in normal climate 20/65.

The concrete compositions are given below:

	Composition per m ³ fresh concrete																				
concrete Ia without "calcined layer silicate based type II addition"	c = 300 kg CEM I 42,5 R according to clause 2.2.11 g = kg aggregates ¹ w = 150 kg water $\left(\frac{w}{c} = 0,50\right)$																				
concrete Ib with "calcined layer silicate based type II addition"	c = 270 kg CEM I 42,5 R according to clause 2.2.11 cls = 30 kg addition ³ g = kg aggregates ¹ m = l admixture ² w = (150 – m) kg water $\left(\frac{w + m}{c + cls} = 0,50\right)$																				
1 Aggregates according to EN 12620 with the following grading curve shall be used: <table border="1" data-bbox="274 1214 1345 1350"> <thead> <tr> <th>Size [mm]</th> <th>0,125</th> <th>0,25</th> <th>0,5</th> <th>1</th> <th>2</th> <th>4</th> <th>8</th> <th>16</th> <th>32</th> </tr> </thead> <tbody> <tr> <td>Passing [% by mass]</td> <td>1,5^{*)}</td> <td>5</td> <td>12</td> <td>18</td> <td>26</td> <td>35</td> <td>50</td> <td>71</td> <td>100</td> </tr> </tbody> </table>		Size [mm]	0,125	0,25	0,5	1	2	4	8	16	32	Passing [% by mass]	1,5 ^{*)}	5	12	18	26	35	50	71	100
Size [mm]	0,125	0,25	0,5	1	2	4	8	16	32												
Passing [% by mass]	1,5 ^{*)}	5	12	18	26	35	50	71	100												
*) recommended value																					
2 Liquid admixture of type "water reducing admixtures" or "plasticizing admixtures" according to EN 934-2 shall be used. The amount of admixture shall be conformed to the flow table (± 2 cm) test value according to EN 12350-5 of the concrete without addition. The amount of admixture shall not exceed the compliance dosage.																					
3 The "calcined layer silicate based type II addition"-sample with the lowest relative compressive strength shall be taken, see clause 2.2.13.																					

NOTE: The recommended maximum dosage of "calcined layer silicate based type II addition" is 11 % by cement mass.

The development of the compressive strength of concrete with addition (average of 3 specimen) and the development of the compressive strength of the reference concrete (average of 3 specimen) shall be stated.

2.2.21 Carbonation of concrete

The carbonation depth of concrete made with addition and without addition is measured according to RILEM CPC 18.

EN 12390-10 can replace RILEM CPC 18 after publication (cp. prEN 12390-10:2017).

The test of carbonation depth is made on prism (40 mm x 40 mm x 160 mm) with aggregates according to EN 12620.

The concrete compositions are given below:

	Concrete mixtures for 3 specimens														
concrete IIa without "calcined layer silicate based type II addition"	c = 450 g CEM III/A 32,5 N ¹ g = 1350 g aggregates ² w = 225 g water $\left(\frac{w}{c} = 0,50 \right)$														
concrete IIb with "calcined layer silicate based type II addition"	c = 405 g CEM III/A 32,5 N ¹ cls = 45 g addition ⁴ g = 1350 g aggregates ² m = ml admixture ³ w = (150 – m) g water $\left(\frac{w + m}{c + cls} = 0,50 \right)$														
1 The reference cement (CEM III/A 32,5 N) shall contain about 50 % by mass granulated blast furnace slag. 2 Aggregates according to EN 12620 with the following grading curve shall be used: <table border="1" data-bbox="274 1182 1232 1317"> <thead> <tr> <th>Size [mm]</th> <th>0,25</th> <th>0,5</th> <th>1</th> <th>2</th> <th>4</th> <th>8</th> </tr> </thead> <tbody> <tr> <td>Passing [% by mass]</td> <td>8</td> <td>21,5</td> <td>36</td> <td>46,5</td> <td>67,5</td> <td>100</td> </tr> </tbody> </table>		Size [mm]	0,25	0,5	1	2	4	8	Passing [% by mass]	8	21,5	36	46,5	67,5	100
Size [mm]	0,25	0,5	1	2	4	8									
Passing [% by mass]	8	21,5	36	46,5	67,5	100									
3 Liquid admixture of type "water reducing admixtures" or "plasticizing admixtures" according to EN 934-2 shall be used. The amount of admixture shall be conformed to the flow table test (± 5 mm) according to EN 1015-3 of the concrete without addition. The amount of admixture shall not exceed the compliance dosage. 4 The "calcined layer silicate based type II addition"-sample with the lowest relative compressive strength shall be taken, see clause 2.2.13.															

NOTE: The recommended maximum dosage of "calcined layer silicate based type II addition" is 11 % by cement mass.

The specimens are prepared according to EN 196-1⁴, except the respect for the gap of (3±1mm) between the bowl and the blade that cannot be respected by the size grading of the sand.

After demoulding half of the specimens are stored immersed in water (20 ± 2) °C until the age of 7 days and the other half until the age of 28 days.

Afterwards the specimens are stored in climate 20/65 and ambient CO₂ content (commonly 350 to 450 p.p.m.).

⁴ If the flow diameter of the fresh concrete exceeds 200 mm or if the fresh concrete shows a tendency to segregation, the content of cement-addition-paste shall be decreased by constant w/(c+cls)-ratio until the flow diameter of the fresh concrete will be between 180 and 200 mm. This concrete mixture shall be taken for the carbonation test.

Measurements of carbonation depth shall be performed after 14, 28, 56, 98 and 140 days for the delivery of the ETA. It is recommended to continue the tests on the same samples after 1, 2 and 5 years in order to verify the obtained results after 140 days and improve the knowledge.

Furthermore the compressive strength is determined according to EN 196-1:

- on the set of specimens n°1, at the age of 35 days (after 7 days pre-storing in water and 28 days in climate 20/65) and at the age of 147 days (after 7 days pre-storing in water and 140 days in climate 20/65),
- on the set of specimens n°2, at the age of 35 days (after 28 days pre-storing in water and 7 days in climate 20/65) and at the age of 168 days (after 28 days pre-storing in water and 140 days in climate 20/65).

The carbonation depth resp. the carbonation speed of the concrete with and without addition is compared to data according to Annex E. The carbonation depth and the carbonation speed of the concrete with and without addition shall be located below or around the limit curve.

Note 1: The carbonation speed v_c is calculated by linear regression with:

$$d_c = d_0 + v_c \cdot \sqrt{t_c} \text{ expressed in mm / } \sqrt{\text{d}}$$

with:

d_c = carbonation depth (mm)

t_c = duration of carbonation (days)

v_c = carbonation speed (in $\text{mm} / \sqrt{\text{day}}$)

d_0 = carbonation depth at time $t = 0$; this specific parameter which depends on the storage and will be lower at a later start of testing the carbonation.

The carbonation depth and the carbonation speed of the concrete with addition and without addition shall be stated.

2.2.22 Freeze-thaw resistance

Method 1: Freeze-thaw resistance (Cube-Procedure) - FT_{cube}

The freeze-thaw resistance of concrete with addition is determined according to CEN/TS 12390-9 ("cube procedure").

The freeze-thaw resistance ("cube procedure") is tested on the following concrete composition:

	Composition per m ³ fresh concrete									
concrete III with "calcined layer silicate based type II addition"	$c = 270 \text{ kg CEM I 32,5 R according to EN 197-1}$ $cls = 30 \text{ kg addition}^1$ $g = \dots \text{ kg aggregates}^2$ $m = \dots \text{ l if applicable admixture}^3$ $w = (180 - m) \text{ g water}$ $\left(\frac{w + m}{c + cls} = 0,60 \right)$									
1	The "calcined layer silicate based type II addition"-sample with the lowest relative compressive strength shall be taken, see clause 2.2.13.									
2	Aggregates according to EN 12620 with the following grading curve shall be used:									
	Size [mm]	0,125	0,25	0,5	1	2	4	8	16	32
	Passing [% by mass]	1,5 ⁴⁾	5	23	35	45	56	70	85	100

*) recommended value

- 3 Liquid admixture of type "water reducing admixtures" according to EN 934-2 shall be used. The fresh concrete shall be adjusted to flow class F3 according to EN 206.

NOTE: The recommended maximum dosage of "calcined layer silicate based type II addition" is 11 % by cement mass.

The scaling shall be measured after 10, 25, 50, 75 and 100 freeze-thaw cycles.

Furthermore the compressive strength of concrete III is determined according to EN 12390-3 at 28 days. Concrete III is immersed in water after demoulding until the age of 7 days. Afterwards the specimens are stored in normal climate 20/65.

The scaling after 100 freeze-thaw-cycles (Cube-procedure) shall be stated.

Method 2: Freeze-thaw resistance (CF-Procedure) - FT_{CF} (Reference method)

The freeze-thaw resistance of concrete with and without addition is determined according to CEN/TS 12390-9 ("CF-Procedure"). The internal structural damage is determined according to CEN/TR 15177.

The freeze-thaw resistance ("CF-Procedure") is tested on the following concrete compositions

	Composition per m ³ fresh concrete																
concrete IVa without "calcined layer silicate based type II addition"	c = 320 kg CEM I 42,5 R according to clause 2.2.11 g = kg aggregates ¹ w = 160 kg water $\frac{w}{c} = 0,50$																
concrete IVb with "calcined layer silicate based type II addition"	c = 288 kg CEM I 42,5 R according to clause 2.2.11 cls = 32 kg addition ² g = kg aggregates ¹ m = ml admixture ³ w = (160 – m) g water $\left(\frac{w + m}{c + cls} = 0,50 \right)$																
1	Aggregates according to EN 12620 with the following grading curve shall be used:																
	<table border="1"> <thead> <tr> <th>Size [mm]</th> <th>0,25</th> <th>0,5</th> <th>1</th> <th>2</th> <th>4</th> <th>8</th> <th>16</th> </tr> </thead> <tbody> <tr> <td>Passing [% by mass]</td> <td>6</td> <td>14</td> <td>22</td> <td>32</td> <td>46</td> <td>68</td> <td>100</td> </tr> </tbody> </table>	Size [mm]	0,25	0,5	1	2	4	8	16	Passing [% by mass]	6	14	22	32	46	68	100
Size [mm]	0,25	0,5	1	2	4	8	16										
Passing [% by mass]	6	14	22	32	46	68	100										
2	The "calcined layer silicate based type II addition"-sample with the lowest relative compressive strength shall be taken, see clause 2.2.13.																
3	Liquid admixture of type "water reducing admixtures" according to EN 934-2 shall be used. The fresh concrete shall be adjusted to flow class F3 according to EN 206.																

NOTE: The recommended maximum dosage of "calcined layer silicate based type II addition" is 11 % by cement mass.

Furthermore the compressive strength of concrete IVa and IVb is determined according to EN 12390-3 at 28 days. The specimens are immersed in water after demoulding until the age of 7 days. Afterwards the specimens are stored in normal climate 20/65.

The relative dynamic modulus of elasticity (RDM) and scaling is measured after 0, 4, 10, 16, 22 and 28 freeze-thaw cycles.

The scaling after 28 freeze-thaw cycles (CF-procedure) and the relative dynamic modulus of elasticity (RDM) shall be stated.

2.2.23 Resistance against chloride penetration

The resistance against chloride penetration of concrete with "calcined layer silicate based type II addition" is determined in accordance with the test method given in Annex C.

The resistance against chloride penetration is tested on the concrete composition IVa and IVb (see clause 2.2.22).

The chloride migration coefficient of concrete with "calcined layer silicate based type II addition" and the chloride migration coefficient of the reference concrete at the age of 35 and 97 days shall be stated.

2.2.24 Shrinkage

The shrinkage of concrete with and without addition is determined in accordance with the test method given in Annex D.

The shrinkage of concrete with addition and the shrinkage of the reference concrete shall be stated.

3 ASSESSMENT AND VERIFICATION OF CONSTANCY OF PERFORMANCE

3.1 System(s) of assessment and verification of constancy of performance to be applied

For the products covered by this EAD the applicable European legal act is: Decision 1999/469/EC.

The system is: 1 +

3.2 Tasks of the manufacturer

The cornerstones of the actions to be undertaken by the manufacturer of the product in the procedure of assessment and verification of constancy of performance are laid down in Table 2.

Table 2 Control plan for the manufacturer; cornerstones

No	Subject/type of control	Test or control method	Criteria, if any	Minimum number of samples	Minimum frequency of control
Factory production control (FPC) [including testing of samples taken at the factory in accordance with a prescribed test plan]					
1	Sulfate content	2.2.1	see manu- facturers control plan	1	1/week
2	Silicon dioxide content	2.2.2		1	1/week
3	Aluminium dioxide content	2.2.3		1	1/week
4	Chloride content	2.2.4		1	1/week
5	Loss on ignition (only for powder)	2.2.5		1	1/week
6	Total content of alkalis	2.2.6		1	4/year
7	Sieving residue on 200 µm sieve	2.2.8		1	1/month
8	Specific surface	2.2.9		1	1/week
9	Fineness	2.2.10		1	1/week
10	Initial setting time	2.2.11		1	1/week
11	Soundness	2.2.12		1	1/month
12	Relative compressive strength at 28 days ¹ = activity index	2.2.13		1	1/week
13	pH value (only for slurry)	2.2.14		1	1/week
14	Density of the slurry	2.2.15		1	1/week
15	Dry mass content of the slurry	2.2.16		1	1/week
16	Stability of the slurry	2.2.17		1	1/week

¹ The determination of the relative compressive strength shall be tested on mortar with test cement according to clause 2.2.11.

3.3 Tasks of the notified body

The cornerstones of the actions to be undertaken by the notified body in the procedure of assessment and verification of constancy of performance are laid down in Table 3.

Table 3 Control plan for the notified body; cornerstones

No	Subject/type of control	Test or control method	Criteria, if any	Minimum number of samples	Minimum frequency of control
Initial inspection of the manufacturing plant and of factory production control					
1	acc. to EN 13263-2				
Continuous surveillance, assessment and evaluation of factory production control					
2	acc. to EN 13263-2				
Audit-testing of samples taken by the notified product certification body at the manufacturing plant or at the manufacturer's storage facilities					
3	Sulfate content	2.2.1		1	6/year ^{*)}
4	Silicon dioxide content	2.2.2		1	6/year ^{*)}
5	Aluminium dioxide content	2.2.3		1	6/year ^{*)}
6	Chloride content	2.2.4		1	6/year ^{*)}
7	Loss on ignition (only for powder)	2.2.5		1	6/year ^{*)}
8	Total content of alkalis	2.2.6		1	2/year
9	Sieve residue on sieve 200 µm	2.2.8		1	6/year ^{*)}
10	Specific surface	2.2.9		1	6/year ^{*)}
11	Fineness	2.2.10		1	6/year ^{*)}
12	Initial setting time	2.2.11		1	6/year ^{*)}
13	Soundness	2.2.12		1	6/year ^{*)}
14	Relative compressive strength at 28 days ¹ = activity index	2.2.13		1	6/year ^{*)}
15	pH value (only for slurry)	2.2.14		1	6/year ^{*)}
16	Density of the slurry	2.2.15		1	6/year ^{*)}
17	Dry mass content of the slurry	2.2.16		1	6/year ^{*)}
18	Stability of the slurry	2.2.17		1	6/year ^{*)}
*) 6/year means 1 testing within 2 month					
¹ The determination of the relative compressive strength shall be tested on mortar with test cement according to clause 2.2.11.					

4 REFERENCE DOCUMENTS

EN 196-1:2016	Methods of testing cement — Determination of strength
EN 196-2:2013	Methods of testing cement — Chemical analysis of cement
EN 196-3:2016	Methods of testing cement — Determination of setting time and soundness
EN 197-1:2011	Cement — Part 1: Composition, specification and conformity criteria for common cements
EN 206:2013 + A1:2016	Concrete — Part 1: Specification, performance, production and conformity
EN 450-1:2012	Fly ash for concrete – Part 1: Definition, specifications and conformity criteria
EN 451-2:2017	Methods of testing fly ash — Part 2: Determination of fineness by wet sieving
EN 933-10:2009	Tests for geometrical properties of aggregates - Part 10: Assessment of fines - Grading of filler aggregates (air jet sieving)
EN 934-1:2008	Admixtures for concrete, mortar and grout - Part 1: Common requirements
EN 934-2:2009+A1:2012	Admixtures for concrete, mortar and grout - Part 2: Concrete admixtures - Definitions, requirements, conformity, marking and labelling
EN 1015-3:1999 +A1:2004 + A2:2006	Methods of test for mortar for masonry - Part 3: Determination of consistence of fresh mortar (by flow table)
EN 1015-6:1998 + A1:2006	Methods of test for mortar for masonry - Part 6: Determination of bulk density of fresh mortar
EN 1015-7:1998	Methods of test for mortar for masonry - Part 7: Determination of air content of fresh mortar
EN 1744-1:2009 +A1:2012	Tests for chemical properties of aggregates — Part 1 Chemical analysis
EN 12350-5:2009	Testing fresh concrete - Part 5: Flow table test
EN 12390-2:2009	Testing hardened concrete – Part 2: Making and curing specimens for strength tests
EN 12390-3:2009	Testing hardened concrete — Part 3: Compressive strength of test specimens
prEN 12390-10:2017	Testing hardened concrete — Part 10: Determination of the carbonation resistance of concrete at atmospheric levels of carbon dioxide
EN 12620:2002 + A1:2008	Aggregates for concrete
EN 13263-1:2005 + A1:2009	Silica fume for concrete - Part 1: Definitions, requirements and conformity criteria
EN 13263-2:2005 + A1:2009	Silica fume for concrete – Part 2: Conformity evaluation

EN 15167-1:2006	Ground granulated blast furnace slag for use in concrete, mortar and grout - Part 1: Definitions, specifications and conformity criteria
CEN/TS 12390-9:2016	Testing hardened concrete - Part 9: Freeze-thaw resistance, Scaling
CEN/TS 15364:2006	Characterization of waste - Leaching behaviour tests - Acid and base neutralisation capacity test
CEN/TR 15177:2006	Testing the freeze-thaw resistance of concrete - Internal structural damage
CR 1901:1995	Regional specifications and recommendations for the avoidance of damaging alkali-silica reactions in concrete
EN ISO 2811-1:2016	Paints and varnishes - Determination of density - Part 1: Pycnometer method (ISO 2811-1:2016)
ISO 3310-1:2016-08	Test sieves – Technical requirement and testing - Part 1: Test sieves of metal wire cloth
ISO 4316:1977-08	Surface active agents; Determination of pH of aqueous solutions; Potentiometric method
ISO 9277:2010-09	Determination of the specific surface area of solids by gas adsorption using the BET method
RILEM CPC-18	Measurement of hardened concrete carbonation depth, Materials and structures, Vol. 21, December 1988

ANNEX A – ANALYSIS OF PORE SOLUTION

A.1 References

EN 196-1	Methods of testing cement — Determination of strength
EN 934-2	Admixtures for concrete, mortar and grout - Part 2: Concrete admixtures - Definitions, requirements, conformity, marking and labelling
EN 1015-3	Methods of test for mortar for masonry - Part 3: Determination of consistence of fresh mortar (by flow table)

A.2 Scope

This procedure is for determination of pore-solution of hardened cement paste.

A.3 Cement paste composition

The analysis of the pore-solution shall be tested on the following cement paste composition:

	Cement paste composition
cement paste I without "calcined layer silicate based type II addition"	c = 450 g CEM III/A 32,5 N acc. to clause 2.2.13 w = 270 g water $\left(\frac{w}{c}=0,60\right)$
cement paste II with "calcined layer silicate based type II addition"	c = 405 g CEM III/A 32,5 N acc. to clause 2.2.13 cls = 45 g addition ² m = ml admixture ¹ w = (270 – m) g water $\left(\frac{w+m}{c+cls}=0,60\right)$
1	Liquid admixture of type "water reducing admixtures" or "plasticizing admixtures" according to EN 934-2 shall be used. The amount of admixture shall be conformed to the flow table test (± 5 mm) according to EN 1015-3 of the concrete without addition. The amount of admixture shall not exceed the compliance dosage.
2	"Calcined layer silicate based type II addition"-sample with the lowest relative compressive strength shall be taken, see clause 2.2.13.

NOTE: The recommended maximum dosage of "calcined layer silicate based type II addition" is 11 % by cement mass.

A.4 Preparation of the specimens for the press-out-method

Specimen shall be made with the cement paste composition given in clause A.3 according to EN 196-1. The cement paste shall be filled in 250 ml plastic flasks (diffusion resistant), hermetically sealed and rotated overhead for 24 hours to prevent segregation. Afterwards the specimens shall be stored at 20 °C. Each specimen shall be weighted at test date to control the impermeability of the plastic flask. At the test date the hardened cement paste shall be cut out of the plastic flask and fixed in a cylindrical aperture of the press block.

A.5 Description of the test procedure

The hardened cement paste shall be fixed in the cylindrical aperture of the test cylinder, see Figure A1.

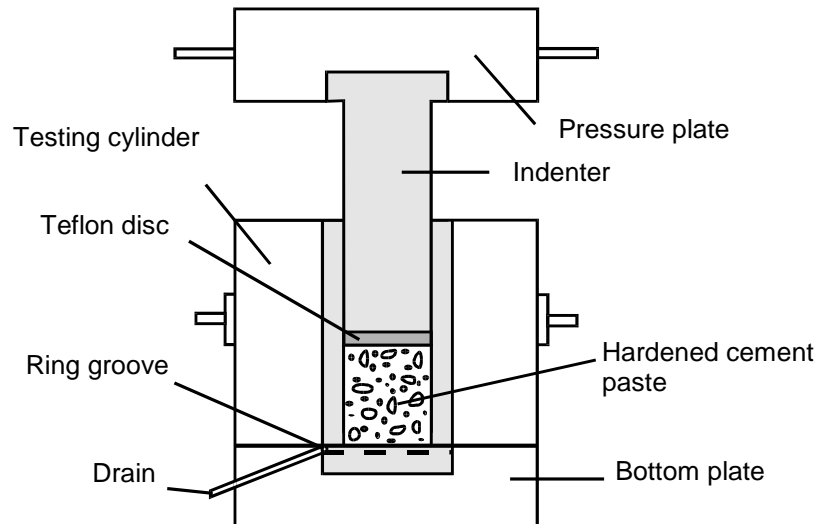


Figure A1: Test equipment to press out pore-solution of hardened cement paste

Afterwards the pressure plate shall be fixed into the testing cylinder. The test equipment shall be installed centrally between the pressure plates of a compression testing machine.

The indenter shall be constantly increased with a load of 3 MPa/s up to a constant maximum hold load of 320 to 360 kN for 2 minutes. After discharging a second loading shall be carried out for 1 minute with a load up to 320 to 360 MPa. The raised compressive strength of the hardened cement paste is about 255 to 285 N/mm², if the circular load area of the steel indenter is about 12,5 cm².

The pore-solution shall be drained off in a synthetic small tube. The small tube shall be sealed off. The pore-solution shall be picked off without air contact. The pore-solution shall be analysed directly to prevent possible changes of the pore-solution e.g. formation of lime, precipitate of dissolved substances of the solution.

A.6 Analysis of the pore-solution

The analysis of the pore-solution includes the determination of the ionic content using Inductively Coupled Plasma Emission Spectroscopy (ICP), the determination of the OH⁻-ionic concentration by titration and the determination of the pH value.

The ionic content of the pore-solution shall be determined by the atom content in g/l using ICP. The atom contents are transformed into ionic contents in mmol/l.

The OH⁻-ionic concentration shall be determined using a combined pH-electrode and calibrate it against KOH solutions of known concentrations.

The pH value of the pore-solution shall be determined with a special electrode (alkali-resistant glass). Previous to every measurement the special electrode shall be calibrated with standard buffer solutions of pH = 6,878, pH = 9,266 and pH = 12,627. For upper pH values no standard buffer solution are available. Mostly this is the case for the determined pH values of the pore-solution. Therefore the pH values can only be determined under the assumption of a quasi-linear curve of the pH value of this area.

The quantity of the pore-solution is divided for the analysis as follows:

- 0,1 ml for the determination of the ionic concentration (ICP)
(1:100 diluted with Aqua_{dist}, charged with nitric acid)
- 1 ml for the determination of the OH⁻-ionics
(1 ml pore-solution + 99 ml Aqua_{dist} diluted)
- remaining quantity for the determination of the pH value (measurements with pH meter)

For the analysis a minimum quantity of 2 ml pore-solution shall be available.

ANNEX B – DETERMINATION OF Ca(OH)_2 -CONTENT

B.1 References

EN 196-1	Methods of testing cement — Determination of strength
EN 934-2	Admixtures for concrete, mortar and grout - Part 2: Concrete admixtures - Definitions, requirements, conformity, marking and labelling
EN 1015-3	Methods of test for mortar for masonry - Part 3: Determination of consistence of fresh mortar (by flow table)

B.2 Scope

This procedure is for determination of Ca(OH)_2 -content of hardened cement paste.

B.3 Cement paste composition

The analysis of the Ca(OH)_2 -content shall be tested on the following cement paste composition:

	Cement paste composition
cement paste I without "calcined layer silicate based type II addition"	$c = 450 \text{ g CEM III/A 32,5 N acc. to clause 2.2.13}$ $w = 270 \text{ g water}$ $\left(\frac{w}{c} = 0,60\right)$
cement paste II with "calcined layer silicate based type II addition"	$c = 405 \text{ g CEM III/A 32,5 N acc. to clause 2.2.13}$ $cls = 45 \text{ g addition}^2$ $m = \dots \text{ ml admixture}^1$ $w = (270 - m) \text{ g water}$ $\left(\frac{w + m}{c + cls} = 0,60\right)$
1	Liquid admixture of type "water reducing admixtures" or "plasticizing admixtures" according to EN 934-2 shall be used. The amount of admixture shall be conformed to the flow table test ($\pm 5 \text{ mm}$) according to EN 1015-3 of the concrete without addition. The amount of admixture shall not exceed the compliance dosage.
2	"Calcined layer silicate based type II addition"-sample with the lowest relative compressive strength shall be taken, see clause 2.2.13.

NOTE: The recommended maximum dosage of "calcined layer silicate based type II addition" is 11 % by cement mass.

B.4 Preparation of the specimens

The test specimen shall be made with the cement paste composition given in clause B.3 according to EN 196-1. The cement paste is filled in 250 ml plastic flasks (diffusion resistant), hermetically sealed and overhead rotated for 24 hours to prevent segregation. Afterwards the specimens shall be stored at 20 °C. Each specimen shall be weighted at test date to control the impermeability of the plastic flask. At the test date the hardened cement paste is cut out of the plastic flask and coarse crushed. Immediately after crushing the sample materials shall be stored in Isopropanol or Acetone for a maximum time of 30 minutes to prevent the cement hydration.

Afterwards the liquid shall be aspirated by a suction filter and water jet pump. Thereby the suction filter shall be covered with a rubber plate. Thereafter the crushed cement paste is dried at 60 °C in a vacuum cabinet.

The crushed cement paste shall be stored sealed in a box up to testing. Before testing the crushed cement paste will be grinded to a particle size $d \leq 125 \mu\text{m}$ and aired.

B.5 Testing method

The Ca(OH)_2 -content shall be determined by using the thermogravimetric analysis method (TGA).

The TGA method detects changes in the mass of a substance during heating due to thermal reactions. This generally involves the splitting-off of volatile substances, such as water or carbon dioxide (CO_2), Figure B1. The hardened cement paste contains hydrate water and a minor degree of containing carbon inorganic compounds. In the temperature range from approximately 100 to about 800 °C the calcium silicate hydrate phases (C-S-H) will be continued drained. Between 500 and 630 °C the water becomes split off from the calcium hydroxide (Ca(OH)_2) in accordance with the following reaction equation:

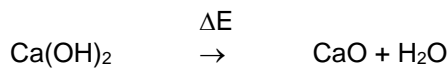
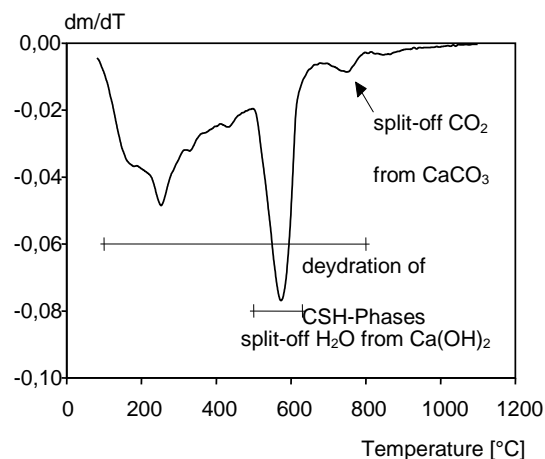
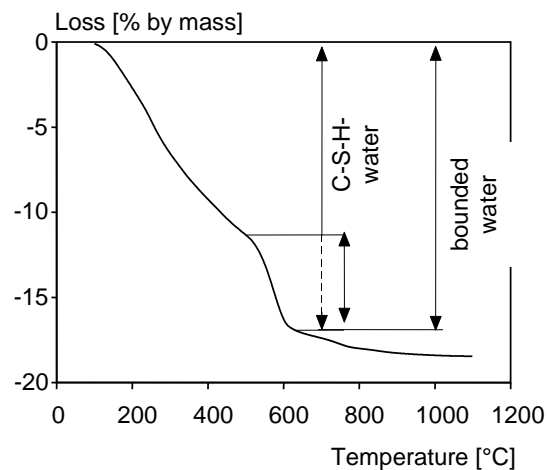


Figure B1: Determination of the bounded water, the Ca(OH)_2 -content and in water contained in the CSH-Phases with TGA (top: TG; down: DTG)



In order to prevent the oxidation of certain substances and to discharge gaseous reaction products, the specimen is located in a nitrogen chamber during the analysis process.

ANNEX C – TESTING THE RESISTANCE AGAINST CHLORIDE PENETRATION BY THE NON-STEADY-STATE-MIGRATION EXPERIMENTS

C.1 References

EN 12390-2 Testing hardened concrete – Part 2: Making and curing specimens for strength tests

C.2 Scope

This procedure is for determination of the chloride migration coefficient in concrete, mortar or cement-based repair materials from non-steady-state migration experiments.

C.3 Field of Application

The method is applicable to hardened specimens cast in the laboratory or drilled from field structures. The chloride migration coefficient determined by the method is a measure of the resistance of the tested material to chloride penetration. This non-steady-state migration coefficient cannot be directly compared with chloride diffusion coefficients obtained from other test methods, such as the non-steady-state immersion test or the steady-state migration test.

C.4 Test Method

C.4.1 Principle

An external electrical potential is applied axially across the specimen and forces the chloride ions outside to migrate into the specimen. After a certain test duration, the specimen is axially split and a silver nitrate solution is sprayed on to one of the freshly split sections. The chloride penetration depth can then be measured from the visible white silver chloride precipitation, after which the chloride migration coefficient can be calculated from this penetration depth.

C.4.2 Reagents and apparatus

C.4.2.1 Reagents

- Distilled or deionised water.
- Calcium hydroxide: $\text{Ca}(\text{OH})_2$, technical quality.
- Sodium chloride: NaCl , chemical quality.
- Sodium hydroxide: NaOH , chemical quality.
- Silver nitrate: AgNO_3 , chemical quality.

C.4.2.2 Apparatus

- Water-cooled diamond saw.
- Migration set-up: One design (see C.1) includes the following parts:
 - Silicone rubber sleeve: inner/outer diameter 100/115 mm, about 150 mm long.
 - Clamp: diameter range 105 ~ 115, 20 mm wide, stainless steel (see Figure C.2).
 - Catholyte reservoir: plastic box, 370 x 270 x 280 mm (length x width x height).
 - Plastic support: (see Figure C.3).
 - Cathode: stainless steel plate (see Figure C.3), about 0,5 mm thick.
 - Anode: stainless steel mesh or plate with holes (see Figure C.4), about 0,5 mm thick.

Other designs are acceptable, provided that temperatures of the specimen and solutions during the test can be maintained in the range of 20 to 25 °C.

- Power supply: capable of supplying 0 ~ 60 V DC regulated voltage with an accuracy of $\pm 0,1$ V.
- Ammeter: capable of displaying current to ± 1 mA.
- Thermometer or thermocouple with readout device capable of reading to ± 1 °C.
- Any suitable device for splitting the specimen.
- Spray bottle.
- Slide calliper with a precision of $\pm 0,1$ mm.
- Ruler with a minimum scale of 1 mm.

C.4.3 Preparation of the test specimen

Six cylinders from each concrete with a diameter of 100 mm and a length of 200 mm shall be made in accordance to EN 12390-2.

The specimens shall be stored for 24 hours in the mould at 20 °C and a relative air humidity of > 95 % r.H. After demoulding the specimens shall be stored immersed in water at 20 ± 5 °C until testing. At an age of 28 days respectively 90 days 3 specimens of each concrete are taken out of the water.

In the middle of each cylinder a 50 ± 2 mm thick slice is cut out. Measure the thickness of each slice with a slide calliper and read to 0,1 mm.

Note 1: The term 'cut' here means to saw perpendicularly to the axis of a core or cylinder, using a water-cooled diamond saw.

Until the test procedure the slices are stored immersed in water. The test procedure is started at an age of 35 days and 97 days.

C.4.4 Test procedure

C.4.4.1 Catholyte and anolyte

The catholyte solution is 10 % NaCl by mass in tap water (100 g NaCl in 900 g water, about 2 N) and the anolyte solution is 0,3 N NaOH in distilled or de-ionised water (approximately 12 g NaOH in 1 litre water). Store the solutions at a temperature of 20 – 25 °C.

C.4.4.2 Temperature

Maintain the temperatures of the specimen and solutions in the range of 20 – 25 °C during the test.

C.4.4.3 Preparation of the test

- Fill the catholyte reservoir with about 12 litres of 10 % NaCl solution.
- Fit the rubber sleeve on the specimen as shown in Figure C.4 and secure it with two clamps. If the curved surface of the specimen is not smooth, or there are defects on the curved surface which could result in significant leakage, apply a line of silicone sealant to improve the tightness.
- Place the specimen on the plastic support in the catholyte reservoir (see Figure C.1).
- Fill the sleeve above the specimen with 300 ml anolyte solution (0,3 N NaOH).
- Immerse the anode in the anolyte solution.
- Connect the cathode to the negative pole and the anode to the positive pole of the power supply.

C.4.4.4 Migration test

- Turn on the power, with the voltage preset at 30 V, and record the initial current through each specimen.
- Adjust the voltage if necessary (as shown in Table C.1). After adjustment, note the value of the initial current again.
- Record the initial temperature in each anolyte solution, as shown by the thermometer or thermocouple.
- Choose appropriate test duration according to the initial current (see Table C.1).
- Record the final current and temperature before terminating the test.

C.4.4.5 Measurement of chloride penetration depth

- Disassemble the specimen by following the reverse of the procedure in C.4.4.3. A wooden rod is often helpful in removing the rubber sleeve from the specimen.
- Rinse the specimen with tap water.
- Wipe off excess water from the surfaces of the specimen.
- Split the specimen axially into two pieces. Choose the piece having the split section more nearly perpendicular to the end surfaces for the penetration depth measurement, and keep the other piece for chloride content analysis (optional).
- Spray 0.1 M silver nitrate solution on to the freshly split section.

- When the white silver chloride precipitation on the split surface is clearly visible (after about 15 minutes), measure the penetration depth, with the help of the slide calliper and a suitable ruler, from the centre to both edges at intervals of 10 mm (see Figure C.5) to obtain seven depths (notes 2, 3 and 4). Measure the depth to an accuracy of 0,1 mm.

Note 2: If the penetration front to be measured is obviously blocked by the aggregate, move the measurement to the nearest front where there is no significant blocking by aggregate or, alternatively, ignore this depth if there are more than five valid depths.

Note 3: If there is a significant defect in the specimen which results in a penetration front much larger than the average, ignore this front as indicative of the penetration depth, but note and report the condition.

Note 4: To obviate the edge effect due to a non-homogeneous degree of saturation or possible leakage, do not make any depth measurements in the zone within about 10 mm from the edge (see Figure C.5).

C.5 Expression of results

C.5.1 Test results

Calculate the non-steady-state migration coefficient from Equation (1):

$$D_{\text{nssm}} = \frac{RT}{zFE} \cdot \frac{x_d - \alpha \sqrt{x_d}}{t} \quad (1)$$

Where:

$$E = \frac{U-2}{L} \quad (2)$$

$$\alpha = 2 \sqrt{\frac{RT}{zFE}} \cdot \text{erf}^{-1} \left(1 - \frac{2c_d}{c_0} \right) \quad (3)$$

D_{nssm} : non-steady-state migration coefficient, m²/s;

z : absolute value of ion valence, for chloride, $z = 1$;

F : Faraday constant, $F = 9,648 \times 10^4$ J/(V·mol);

U : absolute value of the applied voltage, V;

R : gas constant, $R = 8,314$ J/(K·mol);

T : average value of the initial and final temperatures in the anolyte solution, K;

L : thickness of the specimen, m;

x_d : average value of the penetration depths, m;

t : test duration, seconds;

erf^{-1} : inverse of error function;

c_d : chloride concentration at which the colour changes, $c_d \approx 0,07$ N for OPC concrete;

c_0 : chloride concentration in the catholyte solution, $c_0 \approx 2$ N.

Since $\text{erf}^{-1} \left(1 - \frac{2 \cdot 0,07}{2} \right) = 1,28$ the following simplified equation can be used:

$$D_{\text{nssm}} = \frac{0,0239 (273 + T)L}{(U-2)t} \left(x_d - 0,0238 \sqrt{\frac{(273 + T)L x_d}{U-2}} \right) \quad (4)$$

Where:

- D_{nssm} : non-steady-state migration coefficient, $\times 10^{-12} \text{ m}^2/\text{s}$;
 U: absolute value of the applied voltage, V;
 T: average value of the initial and final temperatures in the analyte solution, °C;
 L: thickness of the specimen, mm;
 x_d : average value of the penetration depths, mm;
 t: test duration, hour.

C.6 Appendix

Table C.1: Test voltage and duration for concrete specimen with normal binder content

Initial current L30V (with 30 V)	Applied voltage U (After adjustment)	Possible new initial current I_0	Test duration t
mA	V	mA	hour
$I_0 < 5$	60	$I_0 < 10$	96
$5 \leq I_0 < 10$	60	$10 \leq I_0 < 20$	48
$10 \leq I_0 < 15$	60	$20 \leq I_0 < 30$	24
$15 \leq I_0 < 20$	50	$25 \leq I_0 < 35$	24
$20 \leq I_0 < 30$	40	$25 \leq I_0 < 40$	24
$30 \leq I_0 < 40$	35	$35 \leq I_0 < 50$	24
$40 \leq I_0 < 60$	30	$40 \leq I_0 < 60$	24
$60 \leq I_0 < 90$	25	$50 \leq I_0 < 75$	24
$90 \leq I_0 < 120$	20	$60 \leq I_0 < 80$	24
$120 \leq I_0 < 180$	15	$60 \leq I_0 < 90$	24
$180 \leq I_0 < 360$	10	$60 \leq I_0 < 120$	24
$I_0 \geq 360$	10	$I_0 \geq 120$	6

Note: For specimens with a special binder content, such as repair mortars or grouts, correct the measured current by multiplying by a factor (approximately equal to the ratio of normal binder content to actual binder content) in order to be able to use the above table.

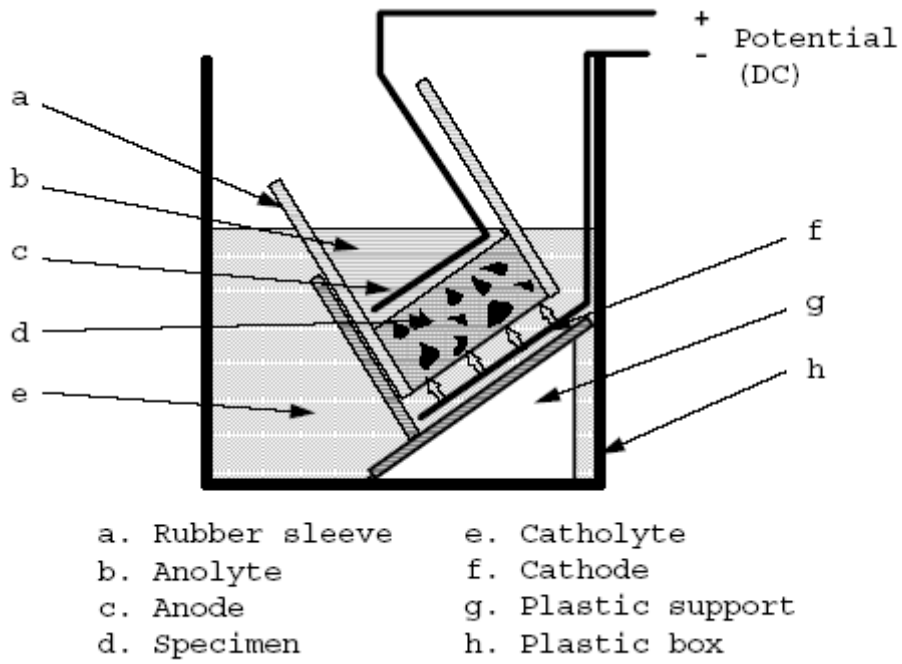


Figure C.1: Arrangement of the migration set-up.



Figure C.2: Stainless steel clamp

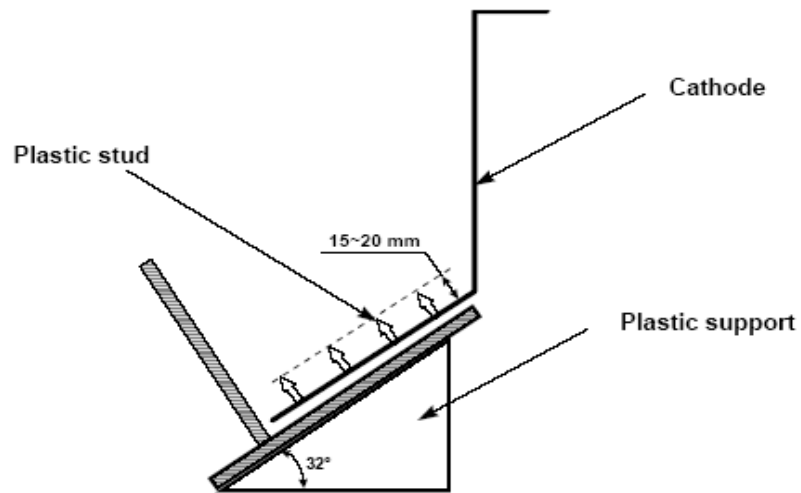


Figure C.3: Plastic support and cathode

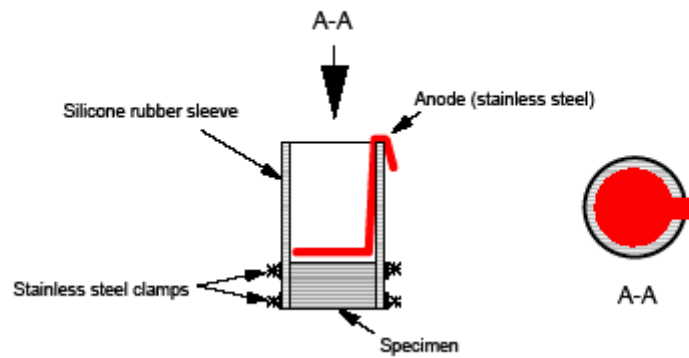


Figure C.4: Rubber sleeve assembled with specimen, clamps and anode

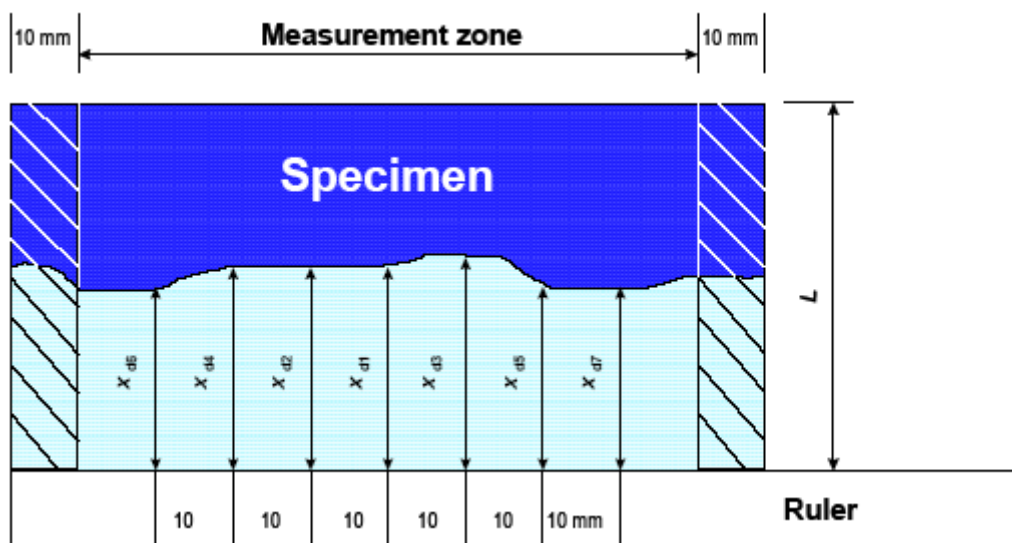


Figure C.5: Illustration of measurement for chloride penetration depths

ANNEX D - SHRINKAGE

D.1 References

EN 197-1	Cement – Part 1: Composition, specifications and conformity criteria for common cement
EN 934-2	Admixtures for concrete, mortar and grout - Part 2: Concrete admixtures - Definitions, requirements, conformity, marking and labelling
EN 12350-5	Testing fresh concrete - Part 5: Flow table test
EN 12620	Aggregates for concrete

D.2 Scope

This procedure is for determination of shrinkage of concrete.

D.3 Concrete composition

The analysis of the shrinkage shall be tested on the following concrete composition:

	Composition per m ³ fresh concrete
concrete Va without "calcined layer silicate based type II addition"	c = 300 kg CEM I 32,5 R according to EN 197-1 g = kg aggregates ¹ w = 180 kg water $\left(\frac{w}{c}=0,60\right)$
concrete Vb with "calcined layer silicate based type II addition"	c = 270 kg CEM I 32,5 R according to EN 197-1 cls = 30 kg addition ³ g = kg aggregates ¹ m = l admixture ² w = (180 – m) kg water $\left(\frac{w+m}{c+cls}=0,60\right)$

1 Aggregates according to EN 12620 with the following grading curve shall be used:

Size [mm]	0,125	0,25	0,5	1	2	4	8	16	32
Passing [% by mass]	1,5 ^{*)}	5	23	35	45	56	70	85	100

*) recommended value

2 Liquid admixture of type "water reducing admixtures" according to EN 934-2 shall be used. The amount of admixture shall be conformed to the flow table (± 2 cm) test value according to EN 12350-5 of the concrete without addition. The amount of admixture shall not exceed the compliance dosage.

3 The "calcined layer silicate based type II addition"-sample with the lowest relative compressive strength shall be taken, see clause 2.2.11.

NOTE: The recommended maximum dosage of "calcined layer silicate based type II addition" is 11 % by cement mass.

D.4 Preparation of the specimens

The test specimen shall be made with the concrete composition given in clause D.3. Preferably 3 cylinders are used with a diameter of 150 mm and a height of 300 mm.

The specimens shall be stored for 24 hours in the mould at 20 °C and a relative air humidity of > 95 % r.H. After demoulding the specimens shall be stored immersed in water at 20 ± 5 °C until the age of 7 days. Afterwards the specimens are stored in normal climate 20/65.

The specimens are provided with gauge marks either during production or after demoulding. These can be affixed to the specimens axially, on lateral surfaces or side surfaces. When arranged on lateral or side surfaces at least 2 opposite measuring sections shall be arranged.

Appropriate storage and/or specimen preparation shall ensure that the moisture transfer occurs only through the lateral or side surfaces.

D.5 Testing method

Usually the measurement of lengths or strain is carried out in the storing room. When stored in a climate test cabinet, the measurement should be completed no later than 10 minutes after removal.

To determine the shrinkage process, measurements shall be carried out at the beginning of the dry storing (at an age of 7 days) and after 1, 2, 3, 7, 14, 28, 56, 90, 180 days etc. A reliable estimation of the final shrinkage is possible after a test period of at least 12 months.

The shrinkage is calculated as ϵ_s

$$\epsilon_{s,t} = (l_t - l_0) / l_0.$$

$\epsilon_{s,t}$ shrinkage at time t,

l_t length of measuring section at time t,

l_0 length of measuring section at beginning of the test.

ANNEX E - EVALUATION OF THE CARBONATION RESISTANCE - C_{DCR}

Carbonation test on concrete (w/c = 0,50) - 7 days pre-storage

	f_c in N/mm ²			Carbonation depth in mm									$F_{C,P}^{0,5}$ in N ^{-0,5} x mm	Carbo. speed in mm / d ^{0,5}	
	Pre-st. 7 d	35 d	140 d main-st.	14 d	28 d	56 d	98 d	140 d	1 a	2 a	5 a	Vc,140d		Vc,5a	
CEM II/B-M (S, V-LL)															
min	28,5	51,2	50,8	0,2	0,4	1,0	1,5	1,8	3,1	3,7	6,8	0,146	0,169	0,147	
max	46,7	66,2	71,0	1,6	1,8	2,7	3,2	3,6	4,7	6,0	10,1	0,187	0,337	0,243	
AVG	38,1	56,6	60,2	0,7	1,0	1,6	2,1	2,7	4,0	5,2	8,6	0,163	0,246	0,203	
s	4,3	4,0	6,0	0,5	0,5	0,5	0,5	0,6	0,6	1,3	1,1	0,010	0,039	0,032	
CEM II/A-LL (C 80 %; LL 20 %)															
min	30,3	36,1	31,6	0,0	0,2	0,6	1,0	1,3	2,3	4,2	7,0	0,150	0,106	0,173	
max	44,3	64,3	63,7	1,0	1,7	2,6	3,5	4,1	6,0	7,8	12,9	0,182	0,409	0,290	
AVG	38,3	54,0	55,0	0,5	0,9	1,5	2,0	2,3	3,8	5,8	9,0	0,162	0,218	0,217	
s	3,3	6,2	7,4	0,3	0,4	0,5	0,6	0,6	1,0	1,0	1,5	0,007	0,079	0,031	
CEM II/B-M (S-V) (C 65 %; S 15 %; V 20 %)															
min	27,1	45,6	45,8	0,0	0,2	1,0	1,4	2,1	3,7	4,9	7,2	0,162	0,166	0,178	
max	38,0	58,8	64,7	1,3	1,8	2,7	3,2	4,0	6,5	8,3	14,3	0,192	0,335	0,327	
AVG	31,8	50,9	55,3	0,6	1,1	1,8	2,3	2,9	4,7	6,3	9,5	0,178	0,277	0,226	
s	3,7	4,7	6,0	0,4	0,5	0,6	0,6	0,7	1,1	1,4	2,3	0,010	0,062	0,049	
CEM II/B-V (C 70 %; V 30 %)															
min	24,9	40,7	43,3	0,0	0,1	0,5	1,0	1,5	3,5	5,3	8,0	0,166	0,177	0,179	
max	36,1	60,9	64,5	1,7	2,4	3,2	4,5	4,8	8,6	9,6	14,3	0,200	0,481	0,318	
AVG	30,1	48,4	51,9	1,1	1,7	2,5	3,1	3,7	5,4	7,2	10,6	0,183	0,316	0,240	
s	3,2	5,0	5,5	0,5	0,6	0,7	0,8	0,9	1,3	1,3	1,7	0,010	0,075	0,036	
CEM III/B															
min	19,2	35,3	36,6	0,1	0,9	1,5	1,5	2,0	3,1	5,5	7,5	0,154	0,167	0,178	
max	41,9	62,0	67,6	1,8	2,6	3,5	4,2	5,0	8,0	10,5	17,1	0,228	0,504	0,394	
AVG	28,3	49,1	52,4	0,9	1,5	2,3	3,0	3,6	5,5	7,6	11,5	0,190	0,330	0,269	
s	4,3	5,3	5,8	0,4	0,4	0,5	0,7	0,7	1,1	1,4	2,4	0,015	0,079	0,055	
CEM I															
min	27,8	45,5	46,6	0,0	0,1	0,1	0,3	0,8	2,0	3,2	5,0	0,152	0,087	0,121	
max	43,3	63,0	64,0	1,4	1,8	2,2	3,2	3,6	6,2	7,8	9,9	0,190	0,391	0,247	
AVG	37,2	56,1	58,1	0,5	0,8	1,3	1,7	2,2	3,4	4,7	6,9	0,165	0,202	0,164	
s	4,2	3,7	3,9	0,3	0,4	0,5	0,7	0,7	0,9	1,0	1,4	0,010	0,072	0,030	

Carbonation test on concrete (w/c = 0,50) - 28 days pre-storage

	f _c in N/mm ²			Carbonation depth in mm									F _{C,P-0,5} in N ^{-0,5} x mm	Carbo. speed in mm / d ^{0,5}	
	Prest. 28 d	35 d	140 d main-st.	14 d	28 d	56 d	98 d	140 d	1 a	2 a	5 a	VC,140d		VC,5a	
CEM II/B-M (S, V-LL)															
min	44,1	50,6	61,2	0,0	0,2	0,3	0,5	0,8	1,8	4,0	4,9	0,129	0,092	0,130	
max	60,2	67,6	76,4	0,7	1,0	1,5	2,2	2,5	3,6	5,1	9,9	0,151	0,274	0,247	
AVG	51,7	58,9	67,2	0,3	0,5	0,9	1,4	1,7	2,5	4,4	7,6	0,139	0,182	0,187	
s	4,0	27,0	30,6	0,2	0,3	0,4	0,5	0,6	0,6	0,6	1,4	0,005	0,062	0,031	
CEM II/A-LL (C 80 %; LL 20 %)															
min	45,1	52,5	60,0	0,0	0,0	0,0	0,4	1,0	2,0	3,0	6,0	0,135	0,102	0,157	
max	54,6	67,8	67,3	0,8	1,2	1,5	2,4	3,0	4,2	6,1	9,6	0,149	0,271	0,221	
AVG	48,0	58,2	62,9	0,3	0,6	0,9	1,3	1,7	3,2	4,7	7,7	0,144	0,170	0,192	
s	2,5	3,7	2,4	0,2	0,3	0,4	0,5	0,5	0,6	0,7	0,9	0,004	0,047	0,017	
CEM II/B-M (S-V) (C 65 %; S 15 %; V 20 %)															
min	35,0	48,3	59,8	0,0	0,0	0,1	0,3	1,0	2,0	2,5	4,4	0,134	0,112	0,109	
max	55,4	65,3	73,1	0,4	0,7	1,4	1,8	2,1	3,3	4,5	8,6	0,169	0,246	0,204	
AVG	46,8	58,7	65,8	0,2	0,5	0,9	1,3	1,7	2,7	3,6	6,4	0,147	0,177	0,154	
s	6,8	5,5	4,2	0,2	0,2	0,4	0,5	0,4	0,5	0,7	1,4	0,012	0,048	0,032	
CEM II/B-V (C 70 %; V 30 %)															
min	35,9	45,6	53,2	0,0	0,1	0,5	0,7	1,4	2,4	3,7	5,9	0,137	0,126	0,144	
max	53,1	62,5	69,9	1,1	1,9	2,4	3,1	4,0	5,2	6,9	11,3	0,167	0,335	0,253	
AVG	44,2	55,4	61,0	0,6	1,0	1,6	2,2	2,6	4,0	5,5	8,3	0,151	0,244	0,195	
s	4,0	4,4	4,6	0,3	0,5	0,5	0,6	0,7	0,8	0,9	1,4	0,007	0,056	0,028	
CEM III/B															
min	36,8	43,6	56,9	0,0	0,0	0,0	0,5	1,0	2,0	2,9	5,0	0,135	0,112	0,122	
max	55,0	63,6	73,0	0,8	1,3	1,9	3,0	3,3	5,4	7,8	11,5	0,165	0,399	0,279	
AVG	47,3	55,2	64,7	0,4	0,7	1,2	1,7	2,1	3,4	5,1	7,9	0,146	0,212	0,193	
s	4,1	4,6	4,2	0,2	0,3	0,4	0,5	0,6	0,9	1,1	1,6	0,007	0,061	0,038	
CEM I															
min	41,6	51,9	59,2	0,0	0,0	0,0	0,2	0,4	1,0	2,2	3,6	0,131	0,037	0,090	
max	58,5	71,3	72,6	1,0	1,1	1,6	2,2	2,4	3,5	4,7	7,8	0,155	0,249	0,177	
AVG	50,3	60,3	66,0	0,3	0,5	0,8	1,1	1,4	2,3	3,3	5,2	0,141	0,128	0,126	
s	3,5	4,1	3,3	0,2	0,3	0,4	0,5	0,6	0,7	0,8	1,0	0,005	0,056	0,022	

