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European Assessment Document for

Portland cement with pozzolanic filler for tropical use



CE

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1 SCOPE OF THE EAD

1.1 Description of the construction product

This EAD covers Portland cement with a filler made of finely grained pozzolanic material containing less than 25% in mass of silicon dioxide (SiO₂). The combination of Portland cement with such filler allows the optimization of the development of the compressive strength and the heat of hydration, conferring to the cement properties that make it appropriate for the tropical climates.

The pozzolanic material are natural materials, consisting essentially of silicon dioxide (SiO₂) and aluminium dioxide (Al₂O₃). Finely ground, these materials enhance the SiO₂ reactivity of the pozzolanic material. As such, it allows to use less pozzolanic material in the cement than the prescription of clause 5.2.3 of EN 197-1¹.

The “Portland cement with pozzolanic filler for tropical use”, referred as the “product” in the document, is not fully covered by harmonised standards EN 197-1, EN 14216 and EAD 150007-00-0301. Table 1.1.1 specifies the main deviations.

Table 1.1.1: Comparison between cement characteristics and specifications

Harmonised technical specification/EADs	Percentage by mass	Strength class
EN 197-1 pozzolanic material reactive silicon dioxide content	≥ 25,0% by mass (see clause 5.2.3.1)	32,5 L, N or R 42,5 L, N or R 52,5 L, N or R (see clause 7.1 table 3)
EN 14216 pozzolanic material reactive silicon dioxide content	≥ 25,0% by mass (see clause 5)	22,5 (see clause 7.1 table 2)
EAD 150007-00-0301 Portland cement with pozzolanic filler, for tropical use	< 25,0% by mass (see clause 1.1 table 1)	According to EN 197-1 table 3: 32,5 L, N or R 42,5 L, N or R 52,5 L, N or R
EAD 150007-01-0301 Portland cement with pozzolanic filler, for tropical use	< 25,0% by mass	22,5 (according to EN 14216 table 2) 32,5 L, N or R 42,5 L, N or R } (according to EN 197-1 table 3)

Composition of the product is defined in Table 1.1.2. Constituents, except Pozzolanic fillers, are defined in EN 197-1 clause 5.

Table 2.1.2: Portland cement with pozzolanic filler, for tropical use and its compositions

Main type	Composition (percentage by mass)		
	Main constituents		Minor additional constituents
	Clinker (K)	Pozzolanic fillers	
Portland cement with pozzolanic filler, for tropical use	65-94	6-35	0-5

¹ All undated references to standards in this EAD are to be understood as references to the dated versions listed in chapter 4.

The range of standard (compressive) strength of the product cement is between 22,5 MPa and 62,5 MPa. Therefore:

- For products with standard (compressive) strength higher than 32,5 MPa:
 - o Mechanical and physical characteristic values given in Table 3 of EN 197-1 are applicable.
 - o Chemical characteristics values given in Table 4 of EN 197-1 are applicable.
- For products with standard (compressive) strength lower than 32,5 MPa:
 - o Mechanical characteristic values given in Table 1.1.1 are applicable.
 - o Physical characteristic values given in Table 3 of EN 197-1 for strength class 32,5 are applicable.
 - o Chemical characteristics values given in Table 4 of EN 197-1 for strength class 32,5 are applicable.

Table 1.1.3 shows the additional product strength class compared to EN 197-1

Table 3.1.3: Mechanical characteristic values for the product when the compressive strength is lower than 32,5 MPa

Strength level	Compressive strength (MPa)			
	2 days	7 days	28 days	
22,5	---	≥ 10,0	≥ 22,5 (*)	≤ 45,5
(*) No individual value lower than 20 MPa.				

The product is not fully covered by EAD 150007-00-0301. Compared to the previous version of the EAD, the following changes are introduced:

- Addition of product compressive strength class (22,5) defined in EN 14216 table 2
- Two new essential characteristics: “Reaction to fire” and “Content, emission and/or release of dangerous substances”.
- The properties “Reactive silicon dioxide content in pozzolanic material” and “Cement composition” (formerly present in BRW1) have been relocated to clause 3.4.
- Improvements of formal aspects and the format of the document.

In deviation from EN 197-1 and EN 14216, the following properties (insoluble residue, loss in ignition) are not to be considered in this EAD, as this product can be assimilated to a type CEM II compound cement or CEM IV pozzolanic cement. Similarly, the C3A content in the clinker, to justify resistance to sulphates, is also irrelevant due to the nature of the product. The durability requirement is assessed with regard to resistance to sulphates by means of a performance test described in clause 2.11.

This EAD covers product that does not contain more than 1,0 % by weight or volume (whichever is the more onerous) of homogeneously distributed organic material.

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, e.g., with regard to the intended end use conditions, 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 as long as the details of the assessment methods as laid down in this EAD are respected.

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

1.2.1 Intended use(s)

The product is intended to be used for preparation of concrete, mortar, grout and other mixes for construction and for the manufacturing of construction products.

The product is intended to be used for the preparation of concretes according to EN 206, mortars, grouts and other mixes for construction or for the manufacturing of construction products, and is specially adapted in tropical climatic areas (tropical zones).

Also standard cements defined in EN 197-1 can be used in the intertropical zone. However, the construction of works in this zone may justify, due to the climate, the use of cements presenting, compared to the cements covered by standard EN 197-1, lower strengths or slower strength development, under the test conditions of standard EN 196-1. The manufacture of such cements from reactive Portland clinker may need the use of another constituent intended to optimise the development of strength and heat of hydration.

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 product for the intended use of 50 years when installed in the works (provided that the "Product" is subject to appropriate installation). These provisions are based upon the current state of the art and the available knowledge and experience.

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.

1.3 Specific terms used in this EAD

K Portland Clinker according to EN 197-1 clause 5.2.1

Abbreviations and symbols:

Carbonation resistance

C_{rcr}	=	Relative carbonation resistance
C_{dcr}	=	Direct carbonation resistance
d_o	[mm]	Initial carbonation depth (at to)
d_c	[mm]	Carbonation depth
v_c	[mm/ \sqrt{day}]	Carbonation speed
t_c	[days]	Duration of carbonation

Resistance to chloride penetration

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.

D_{nss}	=	Non-steady state chloride diffusion coefficient
D_{nssm}	=	Non-steady state chloride migration coefficient
Sulphate Resistance		
S_{FPMm}	=	Modified flat prism method
S_{SPM}	=	Square prism method
$\Delta l_{NS,(ti,T)}$	[mm/m]	Expansion of the length for test solution (0,444% Na_2SO_4), storage temperature (T) and storage time (ti)
$\Delta l_{CH,(ti,T)}$	[mm/m]	Expansion of the length for saturated solution ($Ca(OH)_2$), temperature (T) and storage time (ti)
$\Delta l_{(ti,T)}$	[mm/m]	Expansion of the length for storage temperature (T) and storage time (ti)
$E_{d,NS,(ti,T)}$	[MPa]	Dynamic modulus of elasticity for test solution (0,444% Na_2SO_4), storage temperature (T) and storage time (ti)
$E_{d,CH,(ti,T)}$	[MPa]	Dynamic modulus of elasticity for saturated solution ($Ca(OH)_2$), storage temperature (T) and storage time (ti)
$E_{d,0}$	[MPa]	Dynamic modulus of elasticity for initial measurement (after pre-storage $t = 0$)
$w_{NS,(ti,T)}$	[g]	Mean value of mass for test solution (0,444% Na_2SO_4), storage temperature (T) and storage time (ti)
$w_{CH,(ti,T)}$	[g]	Mean value of mass for saturated solution ($Ca(OH)_2$), storage temperature (T) and storage time (ti)
w_0	[g]	Mean value of mass for initial measurement (after pre-storage $t = 0$)

2 ESSENTIAL CHARACTERISTICS AND RELEVANT ASSESSMENT METHODS AND CRITERIA

2.1 Essential characteristics of the product

Table 2.1.1 shows how the performance of product is assessed in relation to the essential characteristics.

Table 2.1.1 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	Early strength	2.2.1	Class
2	Standard strength	2.2.2	Class
3	Initial setting time	2.2.3	Level
4	Soundness (expansion)	2.2.4	Level
5	Sulphate content	2.2.5	Level
6	Chloride content	2.2.6	Level
7	Heat of hydration	2.2.7	Level
8	Pozzolanicity	2.2.8	Level
9	Carbonation of concrete	2.2.9	Method C_{cr} : Level and/or Method C_{dcr} : Level and/or description
10	Resistance to chloride penetration	2.2.10	Method D_{nss} : Level and/or Method D_{nssm} : Level
11	Sulphate Resistance	2.2.11	Method S_{FPMm} : Description and Level and/or Method S_{SPM} : Level [%]
Basic Works Requirement 2: Safety in case of fire			
12	Reaction to fire	2.2.12	Class
Basic Works Requirement 3: Hygiene, health and the environment			
13	Content, emission and/or release of dangerous substances	2.2.13	Level

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

This chapter is intended to provide instructions for TABs. Therefore, the use of wordings such as “shall be stated in the ETA” or “it has to be given in the ETA” shall be understood only as such instructions for TABs on how results of assessments shall be presented in the ETA. Such wordings do not impose any obligations for the manufacturer and the TAB shall not carry out the assessment of the performance in relation to a given essential characteristic when the manufacturer does not wish to declare this performance in the Declaration of Performance.

2.2.1 Early strength

The early strength of a product is the compressive strength, determined in accordance with EN 196-1 on 2 or 7 days and shall conform to the requirements in table 2.2.2.1 of this EAD.

The early (compressive) strength shall be stated in the ETA, using classes defined in Table 2.2.2.1.

2.2.2 Standard strength

The standard strength of a product is the compressive strength, determined in accordance with EN 196-1 at 28 days and shall conform to the requirements in table 2.2.2.1 of this EAD.

The standard (compressive) strength shall be stated in the ETA, using classes defined in Table 2.2.2.1.

Table 2.2.2.1: Mechanical and physical requirements given as characteristic values

Strength class	Compressive strength MPa				Initial setting time	Soundness (expansion)
	Early strength		Standard strength			
	2 days	7 days	28 days		min	mm
22,5	-	≥ 10,0	≥ 22,5	≤ 42,5	≥ 75	≤ 10
32,5 L	-	≥ 12,0	≥ 32,5	≤ 52,5		
32,5 N	-	≥ 16,0				
32,5 R	≥ 10,0	-	≥ 42,5	≤ 62,5	≥ 60	
42,5 L	-	≥ 16,0				
42,5 N	≥ 10,0	-				
42,5 R	≥ 20,0	-	≥ 52,5	-	≥ 45	
52,5 L	≥ 10,0	-				
52,5 N	≥ 20,0	-				
52,5 R	≥ 30,0	-				

Note: table 2.2.2.1 is an amalgamation of table 2 of EN 14216 and table 3 of EN 197-1.

2.2.3 Initial setting time

The initial setting time of a product shall be determined in accordance with EN 196-3, clause 6 and conform to the requirements in table 2.2.2.1 of this EAD.

The initial setting time (in mm) of the product shall be stated in the ETA.

2.2.4 Soundness

The soundness of a product shall be determined in accordance with EN 196-3, clause 7 and conform to the requirements in table 2.2.2.1 of this EAD.

The soundness (in mm) shall be stated in the ETA.

2.2.5 Sulphate content

The sulphate content, expressed as SO_3 , of a product shall be determined in accordance with EN 196-2, clause 4.4.2.

The sulphate content (in % by mass) shall be stated in the ETA.

The sulphate content shall be in accordance with EN 197-1, Table 4. For products with standard (compressive) strength lower than 32,5 MPa, values given in Table 4 of EN 197-1 for strength class 32,5 are applicable.

2.2.6 Chloride content

The chloride content, expressed as Cl⁻, of a product is determined in accordance with EN 196-2, clause 4.5.16.

The chloride content (in % by mass) shall be stated in the ETA.

The chloride content of a product shall be in accordance with EN 197-1, Table 4. For products with standard (compressive) strength lower than 32,5 MPa, values given in Table 4 of EN 197-1 for strength class 32,5 are applicable.

2.2.7 Heat of hydration

The heat of hydration of low heat cements shall not exceed the characteristic value of 270 J/g, determined in accordance with either EN 196-8 at 7 days or in accordance with EN 196-9 at 41 h.

Low heat common cements shall be identified by the notation "LH".

The heat of hydration (in J/g), time of assessment and the assessment method shall be stated in the ETA.

2.2.8 Pozzolanicity

The pozzolanicity of a product is determined in accordance with EN 196-5.

The pozzolanicity shall be stated in the ETA, expressed as concentrations of hydroxyl ion and calcium ion (expressed as calcium oxide), in mmol/l.

2.2.9 Carbonation resistance

Carbonation resistance shall be assessed by comparison between concretes containing either product or standardised cements by using one of the following methods:

- Relative Carbonation Resistance “C_{rcr}” that shall be tested according to Method 1 stated in clause 2.2.9.1 (reference method).
- Direct Carbonation Method “C_{dcr}” that shall be tested according to Method 2 stated in clause 2.2.9.2.

Assessment results and the test method used shall be stated in the ETA.

2.2.9.1 Method 1: Relative carbonation resistance – C_{rcr}

The carbonation resistance of concrete made with product shall be measured according to EN 12390-10, by using a storage chamber (clauses 5.4 and 6.2 and Annex A of EN 12390-10).

The carbonation resistance shall be tested on concrete IIa (concrete made with the product and concrete IIb (reference concrete)). The composition of concrete IIa and concrete IIb shall be chosen in accordance with limit values described in the exposure class XC1 in Table F1 of EN 206, see Table 2.2.9.1.1.

Table 2.2.9.1.1: Composition of concrete for the determination of carbonation resistance

Composition per m ³ fresh concrete	
concrete IIa	c = 260 kg product g = kg aggregates ¹ $\frac{w}{c} = 0,65$ with w = effective water Strength class = C20/25
concrete IIb	c = 260 kg CEM II/A or B – P according to EN197-1 g = kg aggregates ¹ $\frac{w}{c} = 0,65$ with w = effective water Strength class = C20/25

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

Size [mm]	0,25	0,5	1	2	4	8	16
Passing [% by mass]	6	14	22	32	46	68	100

The composition of the two concretes shall be identical except the origin of the cement. The cement used to make the reference concrete shall be a normalised cement according to EN 197-1. It shall be a blend cement containing pozzolana: CEM II/A or B – P. The cement shall be chosen in order that the pozzolana content range corresponds to the one of the product.

Following specimens are required to perform the test:

- prismatic beams (400 mm x 100 mm x 100 mm) for each concrete for determination of the carbonation depth;
- specimens (cube or cylinder) for each concrete for determination of the compressive strength.

Concrete prismatic beams shall be stored in a storage chamber containing a CO₂ content close to the local normal climate, see EN 12390-10, Annex A.

Measurements of carbonation depth shall be performed after 182 days³.

The mean value of the carbonation depth (d_c) in mm and the carbonation speed (v_c) in $mm/\sqrt{\text{day}}$ after 182 days for the concrete with product (concrete IIa) and with the reference cement (concrete IIb) shall be stated in the ETA. Composition of concretes and reference cement shall be also described in the ETA.

2.2.9.2 Method 2: Direct carbonation resistance – C_{dcr}

The carbonation depth of fine concrete made with product shall be measured according to EN 12390-10, clause 7.

The carbonation resistance shall be tested on prisms (40 mm x 40 mm x 160 mm) with aggregates according to EN 12620 with a maximum size grain of 8 mm. The carbonation resistance shall be tested on (fine) concrete I, see Table 2.2.9.2.1.

³ It is recommended to continue the tests on the same samples for 1, 2 and 5 years in order to verify the obtained results after 140 days and improve the knowledge.

Table 2.2.9.2.1: Composition of (fine) concrete for the determination of carbonation resistance

Concrete mixtures for 3 specimens	
concrete I	c = 450 g product g = 1350 g aggregates ¹ w = 225 g water $\left(\frac{w}{c} = 0,50\right)$ with w = effective water

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

Size [mm]	0,25	0,5	1	2	4	8
Passing [% by mass]	8	21.5	36	46.5	67.5	100

The specimens shall be prepared according to EN 196-1, clause 6, except the consideration of the gap of (3 ± 1) mm between the bowl and the blade that cannot be respected by the size grading of the gravel/sand.

The table 2.2.9.2.2 summarises the number of specimens to be prepared, the storage conditions and the ages for carrying out the tests.

Table 2.2.9.2.2: Determination of carbonation resistance - samples preparation and storage conditions

Casting: number of specimens	Duration of initial storage condition in water at (20 ± 2) °C	Duration carbonation storage condition (20 ± 2) °C and (65 ± 5) %HR and ambient CO ₂ before measurement	
		Compressive strength measurement	Carbonation depth measurement
Specimens set 1 (22 specimens)	7 days	Duration 28 days (age : 35 days): 3 specimens	Duration 14 days: 2 specimens Duration 28 days: 2 specimens Duration 56 days: 2 specimens Duration 98 days: 2 specimens Duration 140 days: 2 specimens Duration 365 days: 2 specimens Duration 730 days: 2 specimens Duration 1825 days: 2 specimens
		Duration 140 days (age : 147 days): 3 specimens	
		Total: 2x3 = 6 specimens	Total: 8x2 = 16 specimens
Specimens set 2: 22 specimens	28 days	Duration 7 days (age : 35 days): 3 specimens	Duration 14 days: 2 specimens Duration 28 days: 2 specimens Duration 56 days: 2 specimens Duration 98 days: 2 specimens Duration 140 days: 2 specimens Duration 365 days: 2 specimens Duration 730 days: 2 specimens Duration 1825 days: 2 specimens
		Duration 119 days (age : 147 days): 3 specimens	
		Total: 2x3 = 6 specimens	Total: 8x2 = 16 specimens
Total: 44 specimens		Total: 12 specimens	Total: 32 specimens

A total of 44 specimens shall be prepared for full characterisation (for each demoulding age (2 demoulding ages): 2 x 3 specimens for compressive strength (age of 35 days and of 147 days) + 8 x 2 specimens for carbonation depth measurement (8 test ages: 14 days, 28 days, 56 days, 98 days, 140 days, 365 days (1 year), 730 days (2 years) and 1825 days (5 years)).

After demoulding half of the specimens (set of specimens n°1) shall be stored immersed in water (20 ± 2) °C until the age of 7 days and the other half (set of specimens n°2) until the age of 28 days.

Afterwards the specimens shall be stored at a temperature of (20 ± 2) °C and a relative air humidity of (65 ± 5) % and ambient CO₂ content (commonly 350 to 450 ppm).

The carbonation depth shall be determined after 14, 28, 56, 98 and 140 days according to EN 12390-10, clause 7, on 2 prisms per aging step⁴.

⁴ It is recommended to continue the tests on the same samples for 1, 2 and 5 years in order to verify the obtained results after 140 days and improve the knowledge.

Furthermore, the compressive strength shall be determined according to EN 196-1, clause 9.2:

- on the set of specimens n°1, at the age of 35 days (after 7 days pre-storing in water and 28 days at a temperature of (20 ± 2) °C and a relative air humidity of (65 ± 5) %) and at the age of 147 days (after 7 days pre-storing in water and 140 days at a temperature of 20 °C and a relative air humidity of (65 ± 5) %);
- on the set of specimens n°2, at the age of 35 days (after 28 days pre-storing in water and 7 days at a temperature of (20 ± 2) °C and a relative air humidity of (65 ± 5) %) and at the age of 168 days (after 28 days pre-storing in water and 140 days at a temperature of (20 ± 2) °C and a relative air humidity of (65 ± 5) %);
- the compressive strength values in MPa shall be the term f_c , to be used in the tables and diagrams provided in Annex A.

Record the depth of carbonation after aging in water and after each aging step in air at a temperature of (20 ± 2) °C and a relative air humidity of (65 ± 5) % and ambient CO₂. The carbonation speed v_c shall be calculated by linear regression with:

$$d_c = d_0 + v_c \cdot \sqrt{t_c} \text{ and then: } v_c = (d_c - d_0) / \sqrt{t_c} \text{ expressed in mm / } \sqrt{\text{d}}$$

with:

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.

d_c = carbonation depth (mm)

t_c = duration of carbonation (days)

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

Note 1: For the assessment of the carbonation resistance the carbonation depth and carbonation speed shall be determined after carbonation duration of 140 days⁵.

Annex A contains tables and diagrams for the evaluation of the carbonation resistance.

The determined carbonation depth together with the compressive strength and the calculated carbonation speed of prisms shall be inserted in the diagrams and figures given in Annex A. Values of d_c , v_c , figures and diagrams are to be stated in the ETA. The table 2.2.9.2.3 below is an example of how the results shall be stated in the ETA.

Table 2.2.9.2.3: Determination of carbonation resistance (summary table for ETA)

No.	Pre-storage time [d]	Compressive strength f_c in [MPa]		Carbonation depth d_c in [mm]							Carbo. Speed in [mm / d ^{0,5}]		
		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,2a
I	7												
II	28												

⁵ It is recommended that the test shall be continued 1, 2 years and/or 5 years to get long term data of the concrete with the test cement.

2.2.10 Resistance to chloride penetration

Resistance to chloride penetration shall be determined according to the methods stated below. Reference method to determine resistance to chloride penetration is non-steady state chloride diffusion coefficient “ D_{nss} ”. Alternatively, Chloride migration coefficient “ D_{nssm} ” shall be used determine resistance to Chloride penetration. Results and method selected shall be stated in the ETA.

2.2.10.1 Method 1: Chloride diffusion coefficient - D_{nss}

The resistance to chloride penetration of concrete with product and of reference concrete shall be determined in accordance EN 12390-11 by the chloride diffusion coefficient.

The resistance against chloride penetration shall be tested on concrete IIIa (concrete made with the product) and concrete IIIb (reference concrete), see Table 2.2.10.1.1.

The composition of concrete IIIa and concrete IIIb shall be chosen in accordance with limit values described in chosen exposure class XS1 in Table F1 of EN 206.

Table 2.2.10.1.1: Composition of concrete for the determination of the resistance to chloride penetration test – method D_{nss}

	Composition per m ³ fresh concrete
concrete IIIa	c = 300 kg product g = kg aggregates ¹ $\frac{w}{c} = 0,50$ with w = effective water Strength class = C30/37
concrete IIIb	c = 300 kg CEM II/A or B – P according to EN 197-1 g = kg aggregates ¹ $\frac{w}{c} = 0,50$ with w = effective water Strength class = C30/37

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

Size [mm]	0,25	0,5	1	2	4	8	16
Passing [% by mass]	6	14	22	32	46	68	100

The composition of the two concretes is identical except the origin of the cement. The cement used to make the reference concrete shall be a normalised cement according to EN 197-1. It shall be a blend cement containing pozzolana: CEM II/A or B – P. The cement shall be chosen in order that its reactive silica content range corresponds to the one of the product.

The following steps shall be applied:

- Vacuum saturation of the profile specimens (EN 12390-11 clause 6.2.1).
- Sealing surfaces other than the surface to be exposed, method a (EN 12390-11 clause 6.2.2).
- Profile specimen for immersion (EN 12390-11 clause 6.2.3).
- Chloride exposure solution (3 % NaCl solution) (EN 12390-11 clause 7.1.1).
- Exposure temperature: 20 °C ± 2 °C (EN 12390-11 clause 7.1.2).
- Exposure method: immersion (EN 12390-11 clause 7.2.2).
- Exposure period: 90 days (EN 12390-11 clause 7.3).
- Determination on chloride content in % by mass: in accordance with EN 12390-11 clause 7.4 and with profile grinding as described in Table 1 of EN 12390-11 (EN 12390-11 clause 7.5).

The chloride diffusion coefficient (D_{nss}) of the two concretes, after 90 days of exposure shall be stated in the ETA.

2.2.10.2 Method 2: Chloride migration coefficient - D_{nssm}

The resistance to chloride penetration of concrete with the product and with Portland cement CEM I according to EN 197-1 as reference shall be determined in accordance with the test method given in Annex B.

The resistance to chloride penetration shall be tested on concrete IVa and IVb, see Table 2.2.10.2.1.

Table 2.2.10.2.1: Composition of concrete for the determination of the resistance to chloride penetration test – method D_{nssm}

	Composition per m ³ fresh concrete
concrete IVa	c = 320 kg product g = kg aggregates ¹ $\frac{w}{c} = 0,50$ with w = effective water
concrete IVb	c = 320 kg CEM I according to EN 197-1 g = kg aggregates ¹ $\frac{w}{c} = 0,50$ with w = effective water

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

Size [mm]	0,25	0,5	1	2	4	8	16
Passing [% by mass]	6	14	22	32	46	68	100

For the test method given in Annex B, the chloride migration coefficient of concrete (D_{nssm}) with the product shall be compared to the chloride migration coefficient of the reference concrete at an age 35 and 97 days.

The chloride migration coefficients ($D_{nssm,35}$ $D_{nssm,97}$), for the concrete with the product and for the reference concrete, at an age of 35 days and 97 days shall be given in the ETA.

2.2.11 Sulphate resistance

Sulphate resistance (external sulphate attack) shall be determined with methods stated below. Reference method to determine sulphate resistance is Flat prism method “ S_{FPMm} ”. Alternatively, square prism method “ S_{SPM} ” shall be used to determine sulphate resistance. Results and method used shall be stated in the ETA.

2.2.11.1 Method 1: Sulphate resistance (Flat prism method) - S_{FPMm}

The sulphate resistance of product shall be determined by the modified flat prism method (S_{FPMm}) given in Annex C on mortar specimens aged up to 104 weeks (2 years)) in 0,444 % Na_2SO_4 -solution and in saturated calcium hydroxide ($Ca(OH)_2$ -solution).

The mean values of the length difference [mm/m] for each tested product and two reference cements (SR-cements according to EN 197-1 clause 7.4.2), test solution (0,444 % Na_2SO_4 -solution and saturated $Ca(OH)_2$ -solution), storage temperature ($T = 5\text{ °C}$ and 20 °C) and storage time ($t_i = 13, 26, 39, 52, 65, 78, 91$ and 104 weeks) shall be given in the ETA:

$$\Delta l_{NS,(ti,T)}$$

$$\Delta l_{CH,(ti,T)}$$

The calculated expansion of the length [mm/m] for each tested cement, storage temperature ($T = 5\text{ °C}$ and 20 °C) and storage time ($t_i = 13, 26, 39, 52, 65, 78, 91$ and 104^6 weeks) shall be given in the ETA:

$$\Delta l_{i,T}$$

The mean value of the dynamic modulus of elasticity for each tested cement, storage solution (0,444 % Na_2SO_4 -solution and saturated $\text{Ca}(\text{OH})_2$ -solution), storage temperature ($T = 5\text{ °C}$ and 20 °C) and storage time ($t_i = 13, 26, 39, 52, 65, 78, 91$ and 104^6 weeks) and also the initial measurement (after pre-storage $t = 0$) shall be given in the ETA:

$$E_{d,NS,(t_i,T)}, E_{d,CH,(t_i,T)} \text{ and } E_{d,0}$$

The mean value of mass of the specimens for each tested cement, storage solution (0,444 % Na_2SO_4 -solution and saturated $\text{Ca}(\text{OH})_2$ -solution), storage temperature ($T = 5\text{ °C}$ and 20 °C) and storage time ($t_i = 13, 26, 39, 52, 65, 78, 91$ and 104^6 weeks) and also the initial measurement (after pre-storage $t = 0$) shall be given in the ETA:

$$W_{NS,(t_i,T)}, W_{CH,(t_i,T)} \text{ and } w_0$$

In addition, a detailed description of the specimens in view of cracks after testing – if any - shall be stated in the ETA.

2.2.11.2 Method 2: Sulphate resistance (Square prism method) - S_{SPM}

The sulphate resistance of the product shall be determined by the test method given in Annex D on mortar specimens aged up to 26 weeks in 4,4 % Na_2SO_4 -solution and in saturated calcium hydroxide ($\text{Ca}(\text{OH})_2$ -solution).

The mean values of the length difference [mm/m] for the product and one reference cement (SR-cements according to EN 197-1 clause 7.4.2), test solution (4,4 % Na_2SO_4 -solution and saturated $\text{Ca}(\text{OH})_2$ -solution), storage temperature ($T = 5\text{ °C}$ and 20 °C) and storage time ($t_i = 14, 28, 56, 91$ and 182 days (182 days only for a storage at 20 °C)) shall be given in the ETA:

$$\Delta l_{NS,(t_i,T)}$$

$$\Delta l_{CH,(t_i,T)}$$

The calculated expansion of the length [mm/m] for the product and one reference cement, storage temperature ($T = 5\text{ °C}$ and 20 °C) and storage time ($t_i = 14, 28, 56, 91$ and 182 days (182 days only for storage at 20 °C)) shall be given in the ETA:

$$\Delta l_{i,T} = \Delta l_{NS,(t_i,T)} - \Delta l_{CH,(t_i,T)}$$

The mean value of the dynamic modulus of elasticity for the product and one reference cement, storage solution (4,4 % Na_2SO_4 -solution and saturated $\text{Ca}(\text{OH})_2$ -solution), storage temperature ($T = 5\text{ °C}$ and 20 °C) and storage time ($t_i = 14, 28, 56, 91$ and 182 days (182 days only for storage at 20 °C) and also the initial measurement (after pre-storage $t = 0$) shall be given in the ETA:

$$E_{d,NS,(t_i,T)}, E_{d,CH,(t_i,T)} \text{ and } E_{d,0}$$

The mean value of mass of the specimens for the product and one reference cement, storage solution (4,4 % Na_2SO_4 -solution and saturated $\text{Ca}(\text{OH})_2$ -solution), storage temperature ($T = 5\text{ °C}$ and 20 °C) and storage time ($t_i = 14, 28, 56, 91$ and 182 days (182 days only for storage at 20 °C)) and also the initial measurement (after pre-storage $t = 0$) shall be given in the ETA:

$$W_{NS,(t_i,T)}, W_{CH,(t_i,T)} \text{ and } w_0$$

In addition, a detailed description of the specimens in view of cracks (as photo) after testing – if any - shall be stated in the ETA.

⁶ The test should be carried out until no significant increase in strain can be seen in the specimens stored in the 0,444% Na_2SO_4 solution.

2.2.12 Reaction to fire

The product, as defined in clause 1.1, is considered to satisfy the requirements of class A1 of the reaction-to-fire performance in accordance with the Decision 96/603/EC as amended by Commission Decision 2000/605/EC and 2003/424/EC, without the need for testing on the basis of it fulfilling the conditions set out in that Decision and its intended use being covered by that Decision.

Therefore, the performance of the product is A1.

2.2.13 Content, emission and/or release of dangerous substances

2.2.11.1 General

The performance of the product regarding the emissions and/or release and, where appropriate, the content of dangerous substances will be assessed on the basis of the information provided by the manufacturer⁷ after identifying the release scenarios taking into account the intended use(s) of the product and the Member States where the manufacturer intends his product to be made available on the market.

The identified intended release scenarios for this product and intended use with respect to dangerous substances are:

S/W1: Product with direct contact to soil, ground- and surface water.

S/W2: Product with indirect contact to soil, ground- and surface water.

2.2.11.2 Leachable Substances

For the intended use covered by the release scenario S/W1 the performance of the product concerning leachable substances shall be assessed. A leaching test with subsequent eluate analysis shall take place, each in triplicate.

Elution test specimens have to be made of concrete with the following composition:

Cement: product, $c = 300 \text{ kg/m}^3$

Water / cement ratio: 0,5

Aggregate: Gravel/Sand according to EN 12620 with the following grading curve:

Size [mm]	0,25	0,5	1	2	4	8	16
Passing [% by mass]	6	14	22	32	46	68	100

Concrete cubes with dimensions of $100 \times 100 \times 100 \text{ mm}^3$ shall be made in accordance with EN 12390-2 (form oil must not be used). Usually, the cubes are removed from the forms after one day.

After removal from the forms, the test specimens are tightly packaged and stored at a temperature of $(20 \pm 2) \text{ }^\circ\text{C}$. The test specimens are generally stored for 56 days. The requirements for storage are fulfilled, when the cubes, for instance, are immediately double-wrapped in plastic foil (at least 0,3 mm thick), and all free edges of the plastic foil are stuck down with adhesive tape.

The eluate is produced by a tank test according to EN 16637-2. The eluates taken after 6 hours, 24 hours, 54 hours, 4 days, 9 days, 16 days, 36 days and 64 days shall be analysed for the following environmentally relevant parameters:

- antimony, arsenic, barium, lead, cadmium, chromium (total), chromate (Cr VI), cobalt, copper, molybdenum, nickel, mercury, thallium, vanadium, zinc,
- chloride (Cl⁻), sulphate (SO₄²⁻), fluoride (F⁻)

⁷ The manufacturer may be asked to provide to the TAB the REACH related information which shall accompany the DoP (cf. Article 6(5) of Regulation (EU) No 305/2011).

The manufacturer is **not** obliged to:

- provide the chemical constitution and composition of the product (or of constituents of the product) to the TAB, or
- provide a written declaration to the TAB stating whether the product (or constituents of the product) contain(s) substances which are classified as dangerous according to Directive 67/548/EEC and Regulation (EC) No 1272/2008 and listed in the "Indicative list on dangerous substances" of the SGDS, taking into account the installation conditions of the construction product and the release scenarios resulting from there.

Any information provided by the manufacturer regarding the chemical composition of the products is not to be distributed to EOTA to other TABs or beyond.

- TOC,
- pH-value, electrical conductivity, odour, colour, turbidity.

The parameters shall be analysed with standardised test methods according to [Table 2.2.11.2.1](#).

Table 2.2.11.2.1: Analytical test methods

Parameter	Test method
antimony (Sb), arsenic (As), barium (Ba), lead (Pb), cadmium (Cd), total chromium (Cr), chromate VI (Cr), cobalt (Co), copper (Cu), molybdenum (Mo), nickel (Ni), mercury (Hg), thallium (Tl), vanadium (V), zinc (Zn), chloride (Cl), sulphate (SO ₄ ²⁻), fluoride (F ⁻)	EN 17195
TOC, pH-value, electrical conductivity	EN 17332
Colour	EN ISO 7887
Turbidity	EN ISO 7027-1

- Measured concentration of the leaching test according to EN 16637-2 of hardened concrete shall be recorded per step for each parameters a) and b) in µg/L and mg/m². Additionally, the cumulatively released quantities shall be expressed for each parameter in mg/m².
- For parameters a) and b) the cumulatively released quantities expressed in mg/m² shall be given in the ETA.

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 product covered by this EAD the applicable European legal act is: Decision 97/555/EC as amended by Commission Decision 2010/683/EU.

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 3.2.1.

Table 3.2.1 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	Early strength (2 or 7 days)	2.2.1	Class	1	2 /week ²⁾ 4 / week ³⁾
2	Standard strength (28 days)	2.2.2	Class	1	2 /week ²⁾ 4 / week ³⁾
3	Initial setting time	2.2.3*	Control plan	1	2 /week ²⁾ 4 / week ³⁾
4	Soundness	2.2.4	≤ 10 min ⁵⁾ upper limit value	1	1 / week ²⁾ 4 / week ³⁾
5	Sulphate content (as SO ³)	2.2.5*	Control plan	1	2 / week ²⁾ 4 / week ³⁾
6	Chloride content	2.2.6*	≤ 0,10 % by mass ⁵⁾ upper limit value	1	2 / month ^{1) 2)} 1 / week ³⁾
7	Heat of hydration (for only low heat cement)	2.2.7	270 J/g for low heat cement	1	1 / month ²⁾ 1 / week ³⁾
8	Pozzolanicity	2.2.8	Passed the test	1	2 / month ²⁾ 1 / week ³⁾
9	Reactive silicon dioxide content in pozzolanic material (Z)	3.4.1*	3.4.1	1	6/ year ^{2) 4)} 1 / month ^{3) 4)}
10	Cement composition	3.4.2*	3.4.2	1	1 / month ²⁾ 1 / week ³⁾
<p>* Other methods than the one indicated may be used provided they give results correlated and equivalent to those obtained with the reference method.</p> <p>1) When none of the test results within a period of 12 months exceeds 50 % of the characteristics value the frequency may be reduced to one per month.</p> <p>2) Routine situation.</p> <p>3) Initial period (3 month).</p> <p>4) The minimum frequency of auto control testing during routine testing and initial period testing and the conformity criteria shall be in accordance with the basic requirements given in the clause entitled "Conformity criteria" in the EN 197-1 clause 9.2.2. For cements not being dispatched continuously, the frequency of testing and the point of sampling shall be as specified in the Works' quality manual (according to EN 197-2 clause 4.3.1).</p> <p>5) Limit values for single results according to EN 197-1, Table 10.</p>					

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 for product are laid down in Table 3.3.1

Table 3.3.1 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	Notified Body will ascertain that the factory production control with the staff and equipment are suitable to ensure a continuous and orderly manufacturing of the product.	Verification of the complete FPC as described in the control plan agreed between the TAB and the manufacturer	According to Control plan	According to Control plan	When starting the production or a new line
Continuous surveillance, assessment and evaluation of factory production control					
2	The Notified Body will ascertain that the system of factory production control and the specified manufacturing process are maintained taking account of the control plan.	Verification of the controls carried out by the manufacturer as described in the control plan agreed between the TAB and the manufacturer with reference to the raw materials, to the process and to the product as indicated in Table 3.2.1	According to Control plan	According to Control plan	1/year (as indicated in EN 197-2)
Audit-testing of samples taken by the notified product certification body at the manufacturing plant or at the manufacturer's storage facilities					
3	See Table 3.2.1 (no. 1 to 8)	See Table 3.2.1	Control plan	1	6/year* (as indicated in EN 197-2)
<p>^{*)} The number of samples taken shall be at least 6 per year for each certified cement dispatched continuously from the factory. When certain certified cements are not dispatched continuously, this frequency and the point of sampling may be altered by mutual agreement between the certification body and the manufacturer.</p> <p>The frequency of control during the initial period (3 months according to EN 197-2) shall be at least one per month.</p>					

3.4 Special methods of control and testing used for the assessment and verification of constancy of performance

3.4.1 Reactive silicon dioxide content in pozzolanic material (Z)

The reactive silicon dioxide content of the pozzolanic material shall be determined in accordance with EN 196-2.

The reactive silicon dioxide content of the pozzolanic material shall be less than 25,0 % by mass.

3.4.2 Cement composition

The composition shall be determined by an appropriate verification method, as CEN/TR 196-4, see EN 197-1, clause 9, Table 6 footnote i.

The composition of the main constituents of the product shall be in the following range:

Pozzolanic material	6 - 35	[% by mass]
Clinker (K)	65 – 94	[% by mass]
Minor additional constituents	0 – 5	[% by mass]

4 REFERENCE DOCUMENTS

EN 196-1:2016	Methods of testing cement – Part 1: Determination of strength.
EN 196-2:2013	Methods of testing cement – Part 2: Chemical analysis of cement.
EN 196-3:2016	Methods of testing cement – Part 3: Determination of setting time and soundness.
EN 196-5:2011	Methods of testing cement – Part 5: Pozzolanicity test for pozzolanic cement
EN 196-8:2010	Methods of testing cement – Part 8: Heat of hydration - Solution method
EN 196-9:2010	Methods of testing cement – Part 9: Heat of hydration - Semi-adiabatic method
EN 197-1:2011	Cement - Part 1: Composition, specification and conformity criteria for common cements.
EN 197-2:2020	Cement - Part 2: Assessment and verification of constancy of performance.
EN 206:2013+A2:2021	Concrete - Specification, performance, production and conformity.
EN 12390-2:2019	Testing hardened concrete - Part 2: Making and curing specimens for strength tests.
EN 12390-10:2018	Testing hardened concrete - Part 10: Determination of the carbonation resistance of concrete at atmospheric levels of carbon dioxide.
EN 12390-11:2015	Testing hardened concrete - Part 11: Determination of the chloride resistance of concrete, unidirectional diffusion.
EN 12390-1:2021	Testing hardened concrete - Part 1: Shape, dimensions and other requirements for specimens and moulds.
EN 12620:2002+A1:2008	Aggregates for concrete.
EN 14146:2004	Natural stone test methods - Determination of the dynamic modulus of elasticity (by measuring the fundamental resonance frequency).
EN 14216:2015	Cement – Composition, specifications and conformity criteria for very low heat special cements
EN 14216:2015	Cement – Composition, specifications and conformity criteria for very low heat special cements
EN 16637-2:2023	Sustainability of construction works - Assessment of environmental performance of buildings - Requirements and guidance.
CEN/TR 196-4:2007	Methods of testing cement - Part 4: Quantitative determination of constituents.
EAD 150007-00-0301	Portland-pozzolana cement for use in tropical conditions.
EN 17195:2023	Construction products: Assessment of release of dangerous substances - Analysis of inorganic substances in eluates
EN 17332:2023	Construction products: Assessment of release of dangerous substances - Analysis of organic substances in eluates
EN ISO 7887:2011	Water quality - Examination and determination of colour
EN ISO 7027-1:2016	Water quality - Determination of turbidity - Part 1 : quantitative methods

ANNEX A - EVALUATION OF THE DIRECT CARBONATION RESISTANCE – C_{DCR}

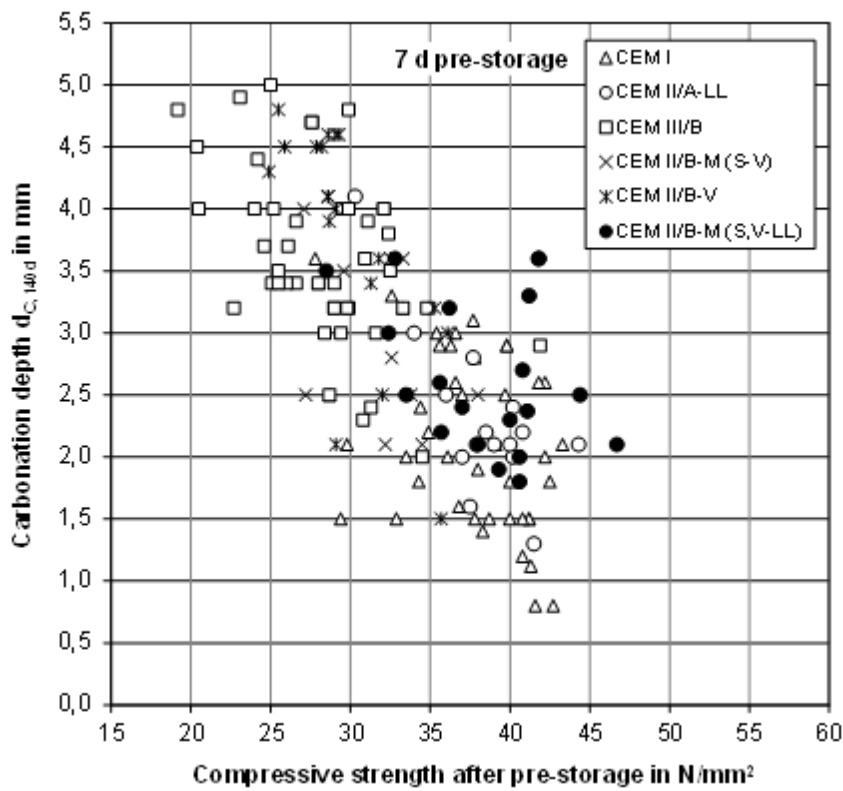
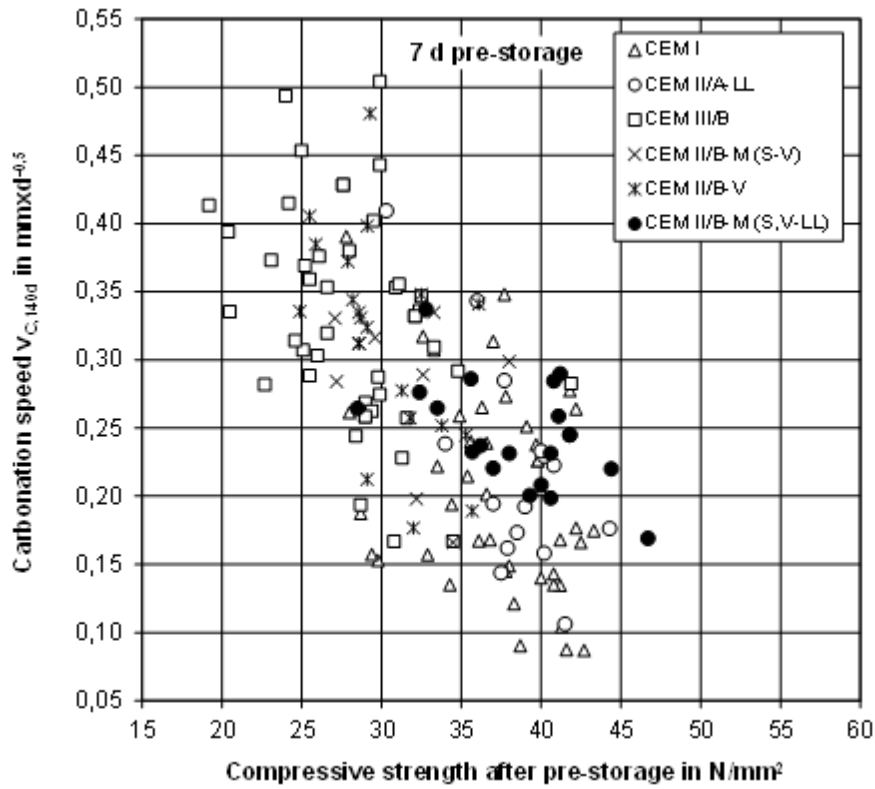
The carbonation depth and the carbonation speed of concrete with product are compared to a data base. The following Tables and Figures result from cement testing for the verification of the carbonation behaviour of different cements (CEM I, CEM II/A-LL, CEM III/B, CEM II/B-M (S-V), CEM II/B V, CEM II/B-M (SV-LL)) and are given as data base.

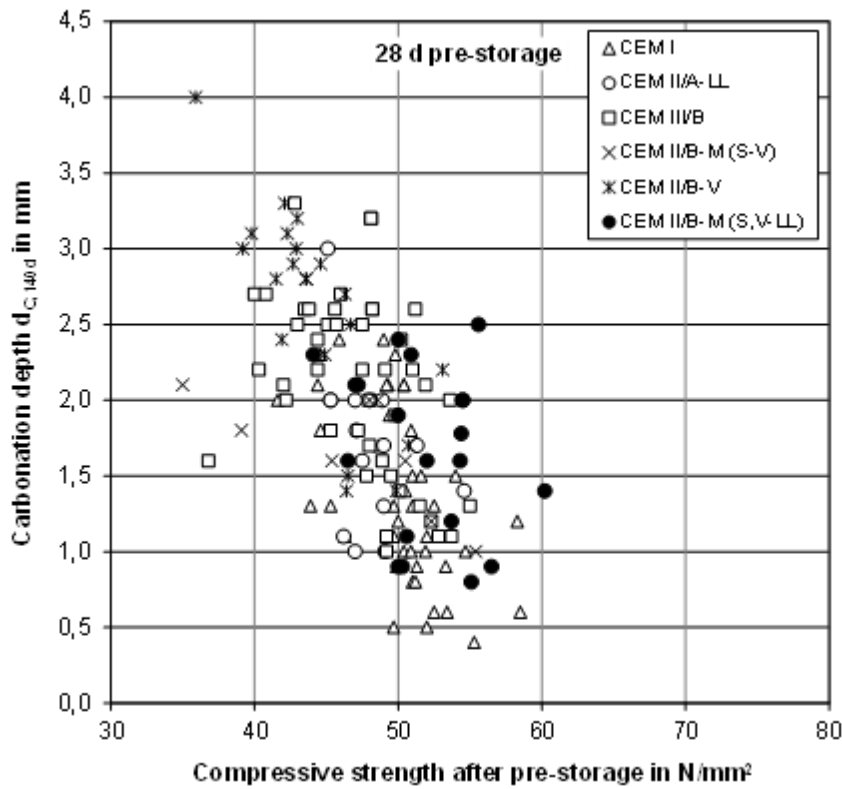
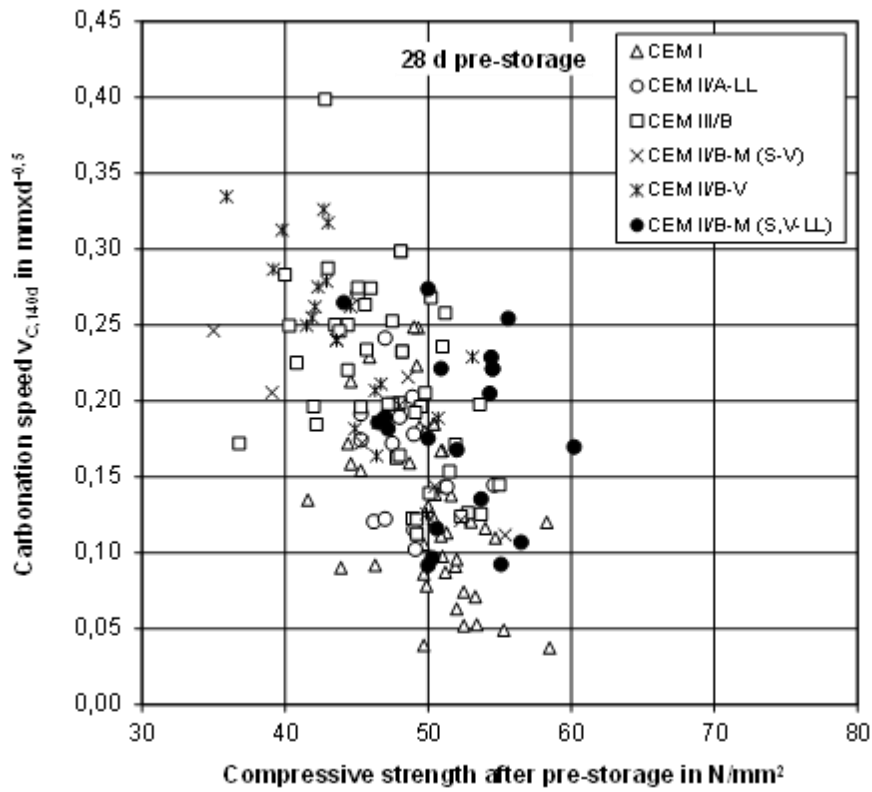
Carbonation test on concrete (w/c = 0,50) – 7 days pre-storage

	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}	
	Pre-st. 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	





ANNEX B – TESTING THE RESISTANCE TO CHLORIDE PENETRATION BY THE NON-STEADY-STATE MIGRATION EXPERIMENTS – CHLORIDE MIGRATION COEFFICIENT D_{nssm}

B.1 References

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

B.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.

B.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.

B.4 Test Method

B.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.

B.4.2 Reagents and apparatus

B.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.

B.4.2.2 Apparatus

- Water-cooled diamond saw.
- Migration set-up: One design (see Figure B.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 B.2).
- Catholyte reservoir: plastic box, 370 × 270 × 280 mm (length × width × height).
- Plastic support: (see Figure B.3).
- Cathode: stainless steel plate (see Figure B.3), about 0.5 mm thick.
- Anode: stainless steel mesh or plate with holes (see Figure B.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.

B.4.3 Preparation of the test specimen

6 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 climate (20/95). After demoulding the specimens shall be stored in water at 20 ± 5 °C until testing. At an age of 28 days, 3 specimens of each concrete are taken out of the water. then at the age of 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.

B.4.4 Test procedure

B.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.

B.4.4.2 Temperature

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

B.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 B.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 B.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.

B.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 B.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 B.1).
- Record the final current and temperature before terminating the test.

B.4.4.5 Measurement of chloride penetration depth

- Disassemble the specimen by following the reverse of the procedure in B.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
- Spray 0,1 M silver nitrate solution on to the freshly split sections.
- 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 B.5) to obtain seven depths (notes 2, 3 and 4). Measure the depth to an accuracy of 0,1 mm.

Note 1: If no penetration front is clearly visible 30 minutes after silver nitrate spraying, a 5% aqueous solution of potassium dichromate ($K_2Cr_2O_7$) can be sprayed to reveal the penetration front.

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 B.5).

B.5 Expression of results

B.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:

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

Where:

D_{nssm} : non-steady-state migration coefficient, $\times 10^{-12}$ m²/s;

U : absolute value of the applied voltage, V;

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

L : thickness of the specimen, mm;

x_d : average value of the penetration depths, mm;

t : test duration, hour.

B.6 Appendix

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

Initial current L30V (with 30 V) mA	Applied voltage U (After adjustment) V	Possible new initial current I_0 mA	Test duration t 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

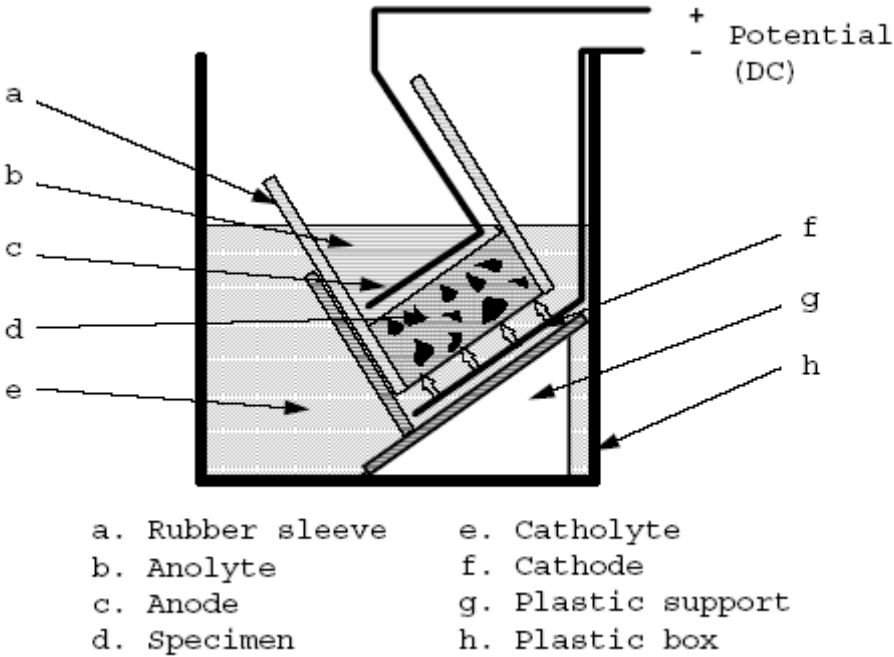


Figure B.1: Arrangement of the migration set-up.



Figure B.2: Stainless steel clamp

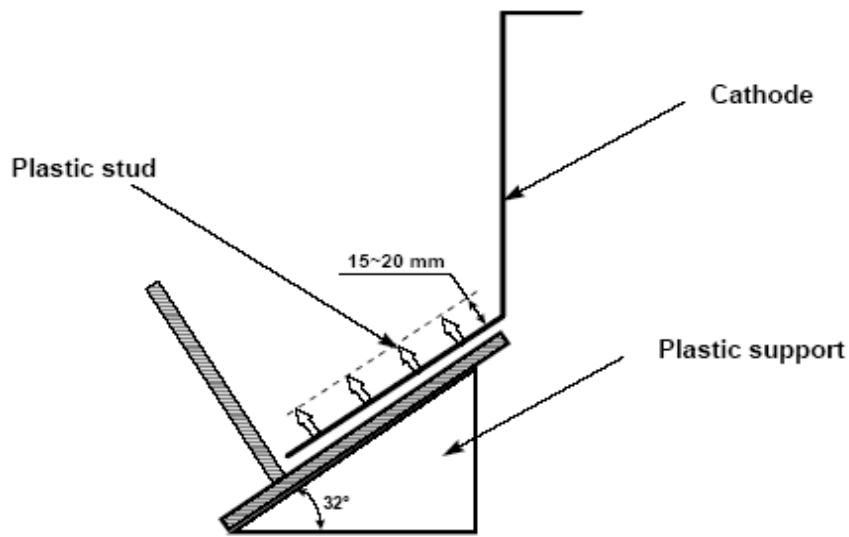


Figure B.3: Plastic support and cathode

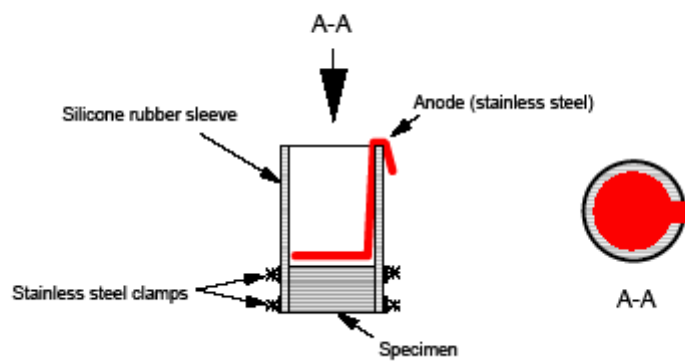


Figure B.4: Rubber sleeve assembled with specimen, clamps and anode

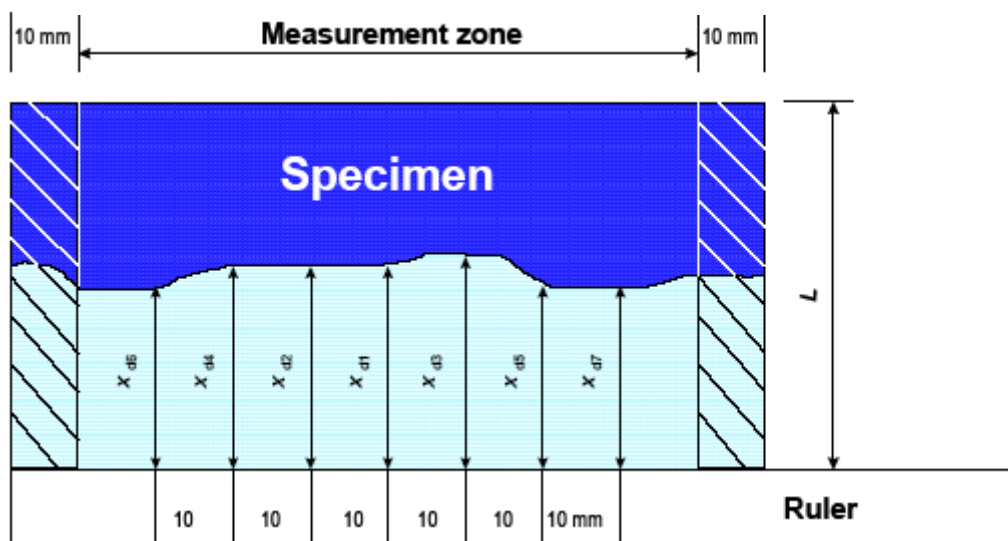


Figure B.5: Illustration of measurement for chloride penetration depths

ANNEX C - TESTING THE SULPHATE RESISTANCE (EXTERNAL SULPHATE ATTACK) – MODIFIED FLAT PRISM METHOD S_{FPMm}

C.1 References

- EN 196-1 Methods of testing cement - Part 1: Determination of strength.
- EN 197-1 Cement - Part 1: Composition, specifications and conformity criteria for common cements.
- EN 14146 Natural stone test methods - Determination of the dynamic modulus of elasticity (by measuring the fundamental resonance frequency).

C.2 General description of the test method

The sulphate resistance shall be determined by the flat prism method (S_{FPMm}) on mortar specimens aged up to minimum of 730 days (104 weeks) in a Na_2SO_4 -solution (NS), and in a saturated calcium hydroxide ($Ca(OH)_2$)-solution (CH) at a storage temperature (T) of $(5 \pm 2) ^\circ C$ (T_5) and $(20 \pm 2) ^\circ C$ (T_{20}).

The length and the mass as well as the longitudinal resonance frequency for the determination of the dynamic modulus of elasticity of the specimens are determined at the beginning of the storage of the specimens in the test solutions and every 13 weeks thereafter.

With the measured length of the specimens after a storage time t_i , the length difference of the flat prisms for each storage solution (NS and CH) and storage temperature (T_5 and T_{20}) shall be calculated as mean value from 3 specimens ($\Delta l_{NS,(t_i,T)}$ and $\Delta l_{CH,(t_i,T)}$).

The difference in elongation between the sulphate storage ($\Delta l_{NS,(t_i,T)}$) and the reference storage ($\Delta l_{CH,(t_i,T)}$) for a storage time (t_i) and a storage temperature (T_5 and T_{20}) is given as expansion of the length ($\Delta l_{t_i,T}$).

In addition, the mass of the specimens ($w_{NS,(t_i,T)}$ and $w_{CH,(t_i,T)}$) and the dynamic modulus of elasticity ($E_{d,NS,(t_i,T)}$ and $E_{d,CH,(t_i,T)}$) shall be determined at a storage time t_i for each storage solution (NS and CH) and storage temperature (T_5 and T_{20}).

One further cement according to EN 197-1 is included in the testing as reference cement. The results of the reference cements shall also be stated in the ETA.

C.3 Cement

The sulphate resistance shall be tested on specimens made of mortar according to EN 196-1 with product and with at least two different SR-cements according to EN 197-1.

C.4 Making of test specimens

Mortar shall be made from each cement (product and the two reference cements according to EN 197-1 as reference cements) in accordance with EN 196-1, clause 6, with a water/cement-ratio of 0,50.

From each mortar 24 flat prisms with the dimensions 10 mm x 40 mm x 160 mm (12 with and 12 without measuring pin) shall be made according to EN 196-1 and be compacted on the vibrating table.

C.5 Storage of test specimens

The specimens shall be stored for (48 ± 2) hours in the mould, protected from drying at a temperature of $(20 \pm 2) ^\circ C$ and a relative air humidity of $\geq 95 \%$.

After demoulding, identify and indelibly mark each flat prism, including an arrow pointing towards the "top" of each prism for the purpose of using a consistent orientation for the measurements. Then examine the flat prisms and record any defects.

After demoulding the flat prisms shall be pre-stored until the age of 28 days, on edge, standing on gratings in saturated Ca(OH)₂-solution at $(20 \pm 2)^\circ\text{C}$.

After pre-storage:

For the sulphate storage (NS), 3 flat prisms with measuring pin and 3 flat prisms without measuring pin shall be stored on edge, standing on gratings in the 0,444 % Na₂SO₄-solution at $(5 \pm 2)^\circ\text{C}$ (= sulphate storage 5 °C = NS,T₅) and at $(20 \pm 2)^\circ\text{C}$ (= sulphate storage 20 °C = NS,T₂₀).

For the reference storage (CH), 3 flat prisms with measuring pin and 3 flat prisms without measuring pin shall be stored standing on edge, standing on gratings in a saturated Ca(OH)₂-solution at $(5 \pm 2)^\circ\text{C}$ (= reference storage 5 °C = CH,T₅) and at $(20 \pm 2)^\circ\text{C}$ (= reference storage 20 °C = CH,T₂₀).

In all storages the ratio of volumes of solution/solid matter shall be 4:1.

During storage of the test specimens the containers shall be air-tight sealed.

The Na₂SO₄ solution shall be replaced every 14 days with a new Na₂SO₄ solution, temperature-controlled at $(5 \pm 2)^\circ\text{C}$ respectively $(20 \pm 2)^\circ\text{C}$.

After a storage period of 90 days, the Na₂SO₄ solution shall be replaced monthly with a new Na₂SO₄ solution tempered at $(5 \pm 2)^\circ\text{C}$ respectively $(20 \pm 2)^\circ\text{C}$ until the end of the test.

The saturated Ca(OH)₂-solution shall be checked every 14 days for its saturation. If needed, it has to be concentrated.

C.6 Initial measurement procedure

After pre-storage, the test specimens shall be dried with a damp cloth after removal from the test solution at a room temperature of $(20 \pm 2)^\circ\text{C}$ and a relative air humidity of 65 %.

Immediately afterwards the initial measurements shall be carried out to prevent the samples from drying out.

The flat prisms shall be weighed with a balance to an accuracy of 0,01 g (w_0).

The length of the flat prisms (with measuring pins) (l_0) shall be measured on a dial gauge with an accuracy of 0,001 mm.

The dynamic modulus of elasticity of the flat prisms (without measuring pins) ($E_{d,0}$) shall be calculated from measurements of the longitudinal resonance frequency ($F_{L,0}$) in accordance to EN 14146, clause 8.2.

Photographs of the flat prisms shall be taken to document their external appearance, as crack formation or spalling.

C.7 Further measurement procedure

After 13, 26, 39, 52, 65, 78, 91 and 104⁸ weeks of storage (t_i) in the respective test solutions (NS and CH) and storage temperature ($T = 5$ and 20), the test specimens shall be removed from the containers to determine the specimen length ($l_{NS,(t_i,T)}$ and $l_{CH,(t_i,T)}$), the mass ($w_{t_i,T}$) and the longitudinal resonance frequency ($F_{L,NS,(t_i,T)}$ and $F_{L,CH,(t_i,T)}$) for the determination of the dynamic modulus of elasticity ($E_{d,NS,(t_i,T)}$ and $E_{d,CH,(t_i,T)}$).

⁸ The test should be carried out until no significant increase in strain can be seen in the specimens stored in the 0,444% Na₂SO₄ solution.

For the tests, the test specimens shall be dried with a damp cloth after removal from the test solution at a room temperature of (20 ± 2) °C and a relative air humidity of 65 %.

Immediately afterwards the measurements shall be carried out to prevent the samples from drying out.

The flat prisms shall be weighed with a balance to an accuracy of 0,01 g ($w_{NS,(ti,T)}$ and $w_{CH,(ti,T)}$).

The length of the flat prisms (with measuring pins) ($l_{NS,(ti,T)}$ and $l_{CH,(ti,T)}$) shall be measured on a dial gauge with an accuracy of 0,001 mm.

The longitudinal resonance frequency of the flat prisms ($F_{L,NS,(ti,T)}$ and $F_{L,CH,(ti,T)}$) shall be determined following EN 14146 to calculate the dynamic modulus of elasticity ($E_{d,NS,(ti,T)}$ and $E_{d,CH,(ti,T)}$).

In additions the external appearance of the flat prisms, as crack formation or spalling shall be documented with a description and photos.

C.8 Analysis

The length difference of the flat prisms (with measuring pins) shall be calculated as mean value from 3 specimens for each storage time (t), storage solution (NS or CH) and storage temperature (T = 5 and 20) ($\Delta l_{NS,(ti,T)}$ and $\Delta l_{CH,(ti,T)}$) by the following formula:

$$\Delta l_{NS,(ti,T)} = (l_{NS,(ti,T)} - l_0) \times 100/160 \text{ [mm/m]}$$

$$\Delta l_{CH,(ti,T)} = (l_{CH,(ti,T)} - l_0) \times 100/160 \text{ [mm/m]}$$

with:

$$l_0 = \text{length of the flat prisms after pre-storage (t = 0) [mm]}$$

$l_{NS,(ti,T)}$ = length of the flat prisms at storage time (t_i) [mm] in Na_2SO_4 -solution at a storage temperature of 5 °C and 20 °C (T)

$l_{CH,(t,T)}$ = length of the flat prisms at storage time (t_i) [mm] in $\text{Ca}(\text{OH})_2$ -solution at a storage temperature of 5 °C and 20 °C (T)

$$t_i = \text{storage time 14, 28, 56, 91 and 182 days}$$

The expansion of length ($\Delta l_{ti,T}$) between the sulphate storage ($\Delta l_{NS,(ti,T)}$) and the reference storage ($\Delta l_{CH,(ti,T)}$) for each storage time shall be calculated by the following formula:

$$\Delta l_{ti,T} = \Delta l_{NS,(ti,T)} - \Delta l_{CH,(ti,T)}$$

ANNEX D - TESTING THE SULPHATE RESISTANCE – SQUARE PRISM METHOD

S_{SPM}⁹

This test method is adapted from the CUR – Civiltechnisch Centrum Uitvoering Research en Regelgeving – Recommendation 48 testing procedure.

D.1 References

EN 196-1:2016 Methods of testing cement - Part 1: Determination of strength.

D.2 Apparatus and solution

D.2.1 Containers

Containers for storage of distilled water and sulphate solution shall have a capacity of 1.5 and 2.5 litres and measure at least 180 mm x 80 mm. Each container must be capable of containing 1.0 ± 0.1 litres of liquid, so that the depth of the liquid reaches at least 25 mm. All the containers must be fitted with light-proof lids and must be manufactured in a material that does not react with its content.

It is allowed to put specimens of different cement types in a single container provided that the chemical composition of the cement is equivalent. In this case 1.0 ± 0.1 litres of liquid are used per three specimens.

D.2.2 Sulphate Solution

The sulphate solution shall have a concentration of 16 ± 0.5 g SO₄ per litre and is prepared by adding Na₂SO₄ or Na₂SO₄ · 10 H₂O of analytical purity to distilled water, or to water of the same purity.

D.3 Cements

The sulphate resistance shall be tested on specimens made of mortar according to EN 196-1 with product and with at least two different SR-cements according to EN 197-1.

D.4 Making of test specimens

The mortar shall be prepared in accordance with paragraph 6 of EN 196-1 standard using EN standard sand, distilled water or water of equal purity. 6 prisms from each mortar with the dimensions 20 mm x 20 mm x 160 mm with two stainless steel studs shall be made and demoulded in accordance with clauses 7 and 8 of EN 196-1.

D.5 Conditioning

The specimens shall be stored according to clause 8.3 EN 196-1. Immediately after demoulding the specimens shall be placed in 2 containers (2 x 3 specimens). Each container shall be filled with 1 litre of with distilled water.

The specimens shall be placed along each other with at least 5 mm space between them, at least 5 mm water above and at least 5 mm distance from the sides of the containers. The specimens shall be placed

⁹ This test method is adapted from the CUR 48 - 2010. Civiltechnisch Centrum Uitvoering Research en Regelgeving (Centre for Civil Engineering Research and Codes) - Recommendation 48 – Assessment of the suitability of new cements for use in concrete and of the equivalent performance of concrete with additions. Procedure, criteria and test methods

on supports at least 2 mm clear from the bottom of the containers, so that the maximum contact between the specimens and the supporting surface is 200 mm².

The specimens shall be always remaining wet and never dry out during removal from the mould and labelling.

D.6 Testing procedure

At the age of 28 days the length of each specimen shall be measured. Before carrying out the measurements, the measuring apparatus must be calibrated using the reference bar. Not the result or adjust the measuring apparatus to the standard value. Remove one specimen at a time and clean the measuring points with a damp cloth. Note the measured value $L(0)$.

After measuring each specimen, replace immediately 3 bars in the container with distilled water (set 1) while the 3 others are put into a new container containing 1 litre of sulphate solution (set 2) for the next storage period.

All the containers shall be stored with a sealed lid at $(20 \pm 2)^{\circ}\text{C}$.

The distilled water shall not be changed during the whole storage period but fill up the water level with additional water if necessary.

The sulphate solution shall be replaced every 28 days.

D.7 Test

Measure the length of the prisms $L(t)$ in the same way after 4, 8, 12, 16, 20 and 26 weeks in the container.

Photos of the specimens shall be taken after every testing to illustrate the formations of the cracks. Record any visible degradation of the specimens.

D.8 Analysis

For each storage period (t), measure the changes in the length of each specimen in relation to the length $L(0)$, as a percentage of the standard length of 160 mm, round to an accuracy of 0,005 %. The percentage expansion of the prisms is to be calculated as mean value for the three specimens stored in distilled water and for the three specimens stored in the sulphate storage. The difference between the average of the three specimens stored in distilled water and the three specimens stored in the sulphate solution is recorded for each storage period.