EUROPEAN ASSESSMENT DOCUMENT

EAD 150008-00-0301

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RAPID SETTING CEMENT

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) No 305/2011 as a basis for the preparation and issuing of European Technical Assessments (ETA).

Contents

1 SCOPE OF THE EAD

1.1 Description of the Construction Product

The construction product is a hydraulic binder which, when mixed with water, forms a paste which rapid sets and hardens by means of hydration reactions, its particular features are:

- raw materials are extracted from a single specific homogeneous geological seam,
- raw meal is burned in a kiln at T < 1300°C in order to obtain low quantities of aluminates and calcium silicates (specially C_2S) ,
- the content of C_2S is higher than 45%,
- it is a pure clinker without/with addition,
- initial setting time is between 1 and 10 minutes.

The product is not fully covered by the following harmonized technical specification: EN 197-1: 2011, since it shows the following differences:

EAD properties	Specifications EN 197-1
Raw material is extracted from a single geological seam	Clinker is a mixture of raw materials (EN 197-1, 5.2.1)
Calcium silicates content of the clinker ≤2/3	Calcium silicates content > 2/3 (EN 197-1, 5.2.1)
Setting time <45 min	Setting time ≥45 min (EN 197-1. 7.1.2)
Soundness (expansion) does not comply with the EN 197-1	Soundness < 10 mm
Loss of ignition can be >5%	Loss of ignition ≤ 5 %

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).

This Rapid setting cement is intended to be used to produce concretes, mortars, grouts and other mixes for construction and for the manufacture of construction products. Due to the rapid setting time of the product, it is more particularly employed for the manufacture of ready-mixed mortar and concrete intended for quick jobs, sprayed concrete, mortar and concrete for repair jobs, etc.

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 concrete incorporating the Rapid setting cement for the intended use of 50 years when installed in the works. 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 works[1].

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] 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.

1.3 Specific terms used in this EAD

Shr_C - Shrinkage (concrete method ISO 1920-8)
Shr_M – Shrinkage (NF P 15-433/UNE 80112)
D_{nss} - Chloride diffusion coefficient (EN 12390-11)
D_{mig} - Chloride migration coefficient (Annex 1.7 of this EAD)
C_{dcr} - Carbonation resistance (*CEN/TS 12390-10)*
C_{rcr} - Relative carbonation resistance (*CEN/TS 12390-10)*
$FT_{cub,}$ FT_{CF} - Freeze-thaw resistance (Cube and CF Procedure) (*CEN/TS 12390-9)*
$FT_{beam\ -}$ Freeze-thaw resistance: Beam-Procedure (CEN/TR 15177)
FTS_{slab}, FTS_{CDF} -Freeze-thaw resistance and de-icing resistance (Slab and CDF -Procedure) (*CEN/TS 12390-9)*

2 ESSENTIAL CHARACTERISTICS AND RELEVANT ASSESSMENT METHODS AND CRITERIA

2.1 Essential Characteristics of the Product

Table 1 shows how the performance of “rapid setting cement” is assessed in relation to the essential characteristics.

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

Nº	Essential characteristic	Assessment method	Level, class, description
Basic Works Requirement 1: Mechanical resistance and stability			
1	Standard strength	See Clause 2.2.1	Class
2	Early strength	See Clause 2.2.2	Level
3	Initial setting time	See Clause 2.2.3	Level
4	Shrinkage	See Clause 2.2.4	$\mathbf{Shr_M}$: level $\mathbf{Shr_C}$ level
5	Soundness	See Clause 2.2.5	Level
5	Loss of ignition	See Clause 2.2.6	Level
7	Sulphate content	See Clause 2.2.7	Threshold level [% by mass] (≤ 4 % by mass acc. to EN 197-1 table 4)
8	Chloride content	See Clause 2.2.8	Threshold level [% by mass] (≤ 0,10 % by mass acc. EN 197-1 table 4, footnote f)
9	Calcium silicate content	See Clause 2.2.9	Level
10	Clinker composition	See Clause 2.2.10	Level
11	Al_2O_3/Fe_2O_3		Level
12	Insoluble residue	See Clause 2.2.11	Level
13	Fineness (Blaine)	See Clause 2.2.12	Level
14	Effect of high temperature on mortar at early age	See Clause 2.2.13	Ratio at 24h, 2d and 3d
15	Resistance to chloride penetration	See Clause 2.2.14	$\mathbf{D_{mig}}$: level $\mathbf{D_{diff}}$: level
16	Carbonation	See Clause 2.2.15	$\mathbf{C_{dcr}}$: level $\mathbf{C_{rcr}}$: level
17	Freeze-thaw resistance (without de-icing agent):	See Clause 2.2.16	$\mathbf{FT_{cube}}$: level $\mathbf{FT_{CF}}$: level $\mathbf{FT_{beam}}$: level
18	Freeze-thaw and de-icing salt resistance	See Clause 2.2.17	$\mathbf{FTS_{CDF}}$: level $\mathbf{FTS_{slab}}$: level
Basic Works Requirement 3: Hygiene, health and the environment			
19	Water-soluble hexavalent chromium content	See Clause 2.2.19	Level (< 2 ppm)

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

2.2.1 Standard Strength.

The standard strength of the product shall be determined according to Annex A1.1. The standard strength value and the mortar composition shall be stated in the ETA.

2.2.2 Early strength.

The early strength of the product at 15 minutes shall be determined according to Annex A1.2. The early strength value and the mortar composition shall be stated in the ETA.

2.2.3 Initial setting time.

The initial setting time of the product shall be determined according to Annex A1.3. The initial setting time and the paste composition shall be stated in the ETA.

2.2.4 Shrinkage.

The shrinkage test method can be determined for concrete as described in ISO 1920-8 (Annex A1.4) (Shr_C) or for mortar as described in French standard NF P 15-433 and Spanish standard UNE 80112 (Shr_M), the composition and sample preparation method are the same than for early and standard strength tests. The shrinkage Shr_M or Shr_C and the composition of the concrete/mortar shall be stated in the ETA.

2.2.5 Soundness (expansion).

The soundness of the product shall be determined in accordance with EN 196-3 and described in Annex A1.5. The soundness (expansion) and the paste composition of the product shall be stated in the ETA.

2.2.6 Loss on ignition.

The loss on ignition of the product shall be determined in accordance with EN 196-2. The loss on ignition of the product shall be stated in the ETA.

2.2.7 Sulphate content.

The sulphate content, as stated SO_3, of the product shall be determined in accordance with EN 196-2. The sulphate content of the product shall not exceed 4 % by mass according to EN 197-1, table 4. The sulphate content of the product shall be stated in the ETA.

2.2.8 Chloride content.

The chloride content of the product shall be determined in accordance with EN 196-2.The chloride content of the product shall not exceed 0,10 % by mass according to EN 197-1, table 4. For pre-stressing applications cements lower values can be required. The chloride content of the product shall be stated in the ETA.

2.2.9 Calcium silicate content.

The calcium silicate content of the product shall be determined in accordance with EN 196-2. The content of the product shall be stated in the ETA.

2.2.10 Clinker phases.

The potential clinker phases shall be calculated with the Bouge-Calculation[2] on the basis of the chemical composition of the Rapid setting cement, or with the XRD-analysis with Rietveld refinement[3]. The chemical composition shall be determined according to EN 196-2. The manufacturer can choose any of these methods. The clinker phases shall be stated in the ETA.

2.2.11 Insoluble residue.

It shall be determined in accordance with EN 196-2 clause 4.4.3. The content of the insoluble residue shall be stated in the ETA.

2.2.12 Fineness (Blaine).

It shall be determined in accordance with EN 196-6. The fineness of the product shall be stated in the ETA.

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2 A standardized version of this simple method is given in ASTM C 150 and in others national standards UNE 80304

If $Al_2O_3/ Fe_2O_3 > 0.64$	*If* $Al_2O_3/ Fe_2O_3 < 0.64$
C_3S = $4.07\ CaO - 7.60\ SiO_2 – 6.72\ Al_2O_3 – 1{,}43\ Fe_2O_3 - 2.85\ SO_3$	**C_3S** = $4.07\ CaO - 7.60\ SiO_2 – 4{,}48\ Al_2O_3 – 2{,}85\ Fe_2O_3 - 2.85\ SO_3$
C_2S = $2.867\ SiO_2 – 0.7544 C_3S$	**C_2S** = $2.867\ SiO_2 – 0.7544 C_3S$
C_4AF = $3.04\ Fe_2O_3$	**C_4AF** = $2{,}10\ Al_2O_3 – 0{,}754\ Fe_2O_3$
C_3A = $2.65\ Al_2O_3-1.69\ Fe_2O_3$	**C_3A** = 0

3 Cement and Concrete Research 41(2011) 133-148. Application of the Rietveld method to the analysis of anhydrous cement.

2.2.13 Effect of high temperature on mortar at early age (3h).

The strength prims of mortar made with the product cured for 3 hours under standard conditions and then subjected to high temperatures is compared to that observed on the reference mortar samples cured at 20 °C for a corresponding period. The ratios of the initial and aged samples at different time are expressed according to the test method described in Annex A1.6. The mortar composition shall be given in the ETA.

2.2.14 Resistance to chloride penetration.

It shall be determined either in accordance with EN 12390-11(Chloride diffusion coefficient-D_{nss}) Annex 1.7 method 1 or in accordance with Annex 1.7 method 2 (Chloride migration coefficient-D_{mig}). The chloride coefficients D_{diff} or D_{nss} and concrete composition shall be given in the ETA.

2.2.15 Carbonation.

It shall be determined in accordance with *CEN/TS 12390-10* either using natural exposure site (A 1.8 method 2: Carbonation resistance–C_{dcr}) or *using a store chamber (A 1.8 method 1:* Relative carbonation resistance–C_{rcr}). The results or diagrams and the concrete composition shall be given in the ETA.

2.2.16 Freeze-thaw resistance without de-icing agent.

It shall be determined either in accordance with CEN/TS 12390-9 (Freeze-thaw resistance: Cube-Procedure-FT_{cube} and/or CF-Procedure-FT_{CF}) or in accordance with CEN/TR 15177 (Freeze-thaw resistance: Beam-Procedure-FT_{beam}), as reported in A1.9. The obtained values and the concrete composition shall be given in the ETA.

2.2.17 Freeze-thaw resistance and de-icing agent.

It shall be determined in accordance with CEN/TS 12390-9 (Freeze-thaw and de-icing resistance: CDF-Procedure-FTS_{CDF} or Slab-Procedure-FT_{slab}) as reported in A1.10. The obtained values and the concrete composition shall be given in the ETA

2.2.18 Water-soluble hexavalent chromium.

Content is determined in accordance with EN 196-10. The content shall be <2ppm (according to (EC) No.1907/2006)

3 ASSESSMENT AND VERIFICATION OF CONSTANCY OF PERFORMANCE

3.1 System 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 97/555/EC as amended by 2010/683/EC. The system is: 1+.

3.2 Tasks of the Manufacturer

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; corner stones

Nº	Subject/type of control	Test or control method	Criteria, if any	Minimum nº samples	Minimum frequency
Factory production control (FPC)					
1	Standard strength	Annex A1.2	Level	1	2/week[1] // 4/week[2]// batch[3]
2	Early strength	Annex A1.2	Level	1	2/week[1] // 4/week[2]// batch[3]
3	Initial setting time	Annex A1.3	Level	1	2/week[1] // 4/week[2]// batch[3]
4	Soundness (expansion)	Annex A1.4	Level	1	2/week[1] // 4/week[2]// batch[3]
5	loss on ignition	EN 196-2	Level	1	2/week[1] // 4/week[2]// batch[3]
6	Sulphate content	EN 196-2	≤ 4%	1	2/week[1] // 4/week[2]// batch[3]
7	Chloride content	EN 196-2	≤ 0,1%	1	2/week[1] // 4/week[2]// batch[3]
8	Chemical Composition**	A 2.2.10	Level	1	1 week[2] / month[1]
[1] routine situation; [2] initial period, [3]discontinuous expedition					

3.3 Tasks of the Notified Body

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

Table 3. Control plan for the notified body;

No	Subject/type of control	Test/control method	Criteria, if any	Minimum nº samples	Minimum frequency control
Initial inspection of the manufacturing plant and of factory production control					
1	acc. to EN 197-2				
Continuous surveillance, judgment and assessment of factory production control (FPC)					
2	acc. to EN 197-2				1/year
Audit-testing of samples taken by the notified product certification body at the manufacturing plant or at the manufacturer’s storage facilities					
4	Standard strength	Annex A1.1	Level	1	6/year*
5	Early strength	Annex A1.2	Level	1	6/year*
6	Initial setting time	Annex A1.3	Level	1	6/year*
7	Soundness (expansion)	Annex A1.4	Level	1	6/year*
8	loss on ignition	EN 196-2	Level	1	6/year*
9	Sulphate content	EN 196-2	≤ 4%	1	6/year*
10	Fineness (Blaine)	EN 196-6	Level	1	6/year*
6/year in case of continuous expedition. In case of discontinuous expedition it will be adapted to its frequency, with the approbation of the notified body					

4 REFERENCE DOCUMENTS

As far as no edition date is given in the list of standards thereafter, the standard in its current version at the time of issuing the European Technical Assessment, is of relevance

EN 196-1	Methods of testing cement - Determination of strength
EN 196-2	Methods of testing cement - Chemical analysis of cement
EN 196-3	Methods of testing cement - Determination of setting time and soundness
EN 196-6	Methods of testing cement - Determination of fineness
EN 196-10	Methods of testing cement - Part 10: Determination of the water-soluble chromium (VI) content of cement
EN 197-1	Cement - Part 1: Composition, specification and conformity criteria for common cements
EN 197-2	Cement - Part 2: Conformity evaluation
EN 480-11	Admixtures for concrete, mortar and grout - Test methods - Part 11: Determination of air void characteristics in hardened concrete
EN 12390-2	Testing hardened concrete - Part 2: Making and curing specimens for strength tests
EN 12390-3	Testing hardened concrete - Part 3: Compressive strength of test specimens
CEN/TS 12390-9	Testing hardened concrete - Part 9: Freeze-thaw resistance, Scaling
CEN/TS 12390-10	Testing hardened concrete. Determination of the relative carbonation resistance of concrete
EN 12390-11	Testing hardened concrete - Determination of the chloride resistance of concrete, unidirectional diffusion
EN 12620	Aggregates for concrete
CEN/TR 15177	Testing the freeze-thaw resistance of concrete - Internal structural damage
ISO 1920-3	Testing of concrete -- Part 3: Making and curing test specimens
ISO 1920-8	Testing of concrete - Part 8: Determination of drying shrinkage of concrete for samples prepared in the field or in the laboratory
RILEM CPC 18	Measurement of hardened concrete carbonation depth, Materials and structures, Vol. 21
NF P 15-433	Methods of testing cement – Determination of shrinkage and swelling
UNE 80112	Methods of cements test. Physical tests. Determination of the shrinkage of drying and swelling in water
UNE 80304	Calculations of potential composition of Portland clinker (http://www.aenor.es/aenor/normas/normas/fichanorma.asp?tipo=N&codigo=N0036301&PDF=Si)
EN 1015-3	Methods of test for mortar for masonry. part 3: determination of consistence of fresh mortar (by flow table)
ASTM C 150	Standard Specification for Portland Cement

ANNEX A: DESCRIPTION OF VERIFICATION METHODS FOR DETERMINING RELEVANT CHARACTERISTICS OF THE CONSTRUCTION PRODUCT

A1.1 Standard strength.

The standard strength is determined in accordance with EN 196-1 except the following points:
Mortar composition (EN 196-1/6.1): sand: 1350±5 g, cement: 675±2 g and water: 270±1 g, w/c=0,4, or sand: 1350 g, cement : 1350 g, water : 510 g, Water/cement ratio is 0.38 (but, If the consistence of this new fresh concrete/mortar varied significantly with the reference fresh concrete/mortar (EN 1015-3 or other methods) other ratio is allowed to obtain a similar consistence with the reference fresh concrete/mortar)

Sand/Rapid setting cement 2, instead of 3 in EN 196-1.
After pouring in the water, mortar is immediately mixed at a speed of 140±5 rpm for 10±1 seconds, then at 285±10 rpm for 15±1 seconds (EN 196-1/6.2).
Compression tests are carried out after 28 days.

A1.2 Early strength.

The early strength of the Rapid setting cement is carried out following A1.1. except for compression tests that are carried out at 15 min ± 1 min.

A1.3 Initial setting time.

The initial setting time assessment method is in accordance with EN 196-3, except the following points: (EN 196-3/5.2.1) Pure paste composition is: Rapid setting cement: 500±1g and water 180±1g, the Water/Rapid setting cement ratio 0.36. After pouring in the water, paste is immediately mixed at a speed of 140±5 rpm for 10±1 seconds, then at 285 ±10 rpm for 15±1 seconds. At least three samples will perform.

A1.4 Method 2: Shrinkage (concrete method) - Shr_C.

The shrinkage of concrete with the "Product" shall be determined according to ISO 1920-8 on 3 specimens with the dimension 75 mm x 75 mm x 280 mm. The shrinkage shall be tested on **concrete I**[4] (table 4). If the consistence of this new fresh concrete/mortar varied significantly with the reference fresh concrete/mortar (EN 1015-3 or other methods) other ratio is allowed to obtain a similar consistence with the reference fresh concrete/mortar.

The specimens are stored for (24 ± 2) hours in the mould, protected from drying at (20 ± 2)°C and > 95 % relative humidity. After demoulding the concrete prisms were cured in water with (20 ± 2) °C for 7 days. At an age of 7 days starting from moulding, the specimens were removed from water and the surface was wiped dry with a damp cloth. The specimens are to be stored in climate (20 ± 2) °C and (65 ± 5) % relative humidity (climate 20/65).

The weight measurement and the length measurement according to ISO 1920-8 are determined immediately after demoulding and curing moist after 24 hour, 3 and 7 days. After moist curing the weight measurement and the length measurement are determined during dry curing at the age after fabrication of 14, 21, 28, 35, 60, 90, 120 and 180 days.

A1.5 Soundness.

The expansion is determined in accordance with EN 196-3 except the following points (EN 196-3/5.2.1): Pure paste composition is Rapid setting cement: 500±1 g and water 180±1g. After pouring in the water, paste is immediately mixed at a speed of 140±5 rpm for 10±1 seconds, then at 285±5 rpm for 15±1 seconds. At least three samples will perform.

A1.6 Effect of high temperature on mortar at early age.

Tests are carried out on samples whose mortar composition and preparation are described in A1.1. Three series of 3 mortar beams for each different temperatures are prepared. The specimens are demolded after 3 hours, and then, one series is kept in water at 20°C ± 2°C, one at 40°C ± 2°C and one at 80°C ± 2°C. All the samples of each series are removed from water and tested according to EN 196-1/8.3 (Compressive strength) after 24h, 2days

[4] Table 4 shows the different dosage of each type of concrete used in this EAD

and 3 days, these results are compared with those of samples stored at 20 °C. Ratios for each time are determined:

$$x = \frac{R.Compressive\ 20ºC - R\ compresive\ xTºC}{\mathrm{R.\ Compressive\ 20ºC}}$$

A 1.7 Resistance to chloride penetration

Method 1: Chloride diffusion coefficient - Dnss. The resistance to chloride penetration of concrete with the "Product" and with Portland cement as reference shall be determined in accordance EN 12390-11 by the chloride diffusion coefficient (non-steady state diffusion coefficient).

The resistance to chloride penetration shall be tested on 3 samples of **concrete IIIa**[2] (concrete made with the "Product") and 2 samples of **concrete IIIb**[2] (reference concrete), see table 4. The chloride diffusion coefficient (D_{nss}) of concrete with the "Product" is compared to the chloride diffusion coefficient of concrete with Portland cement.

Method 2: Chloride migration coefficient - D_{mig}. The chloride migration coefficient (non-steady-state 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.

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:

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.

Reagents: Distilled or deionised water, Calcium hydroxide: $Ca(OH)_2$, technical quality, Sodium chloride: NaCl, chemical quality, Sodium hydroxide: NaOH, chemical quality and Silver nitrate: $AgNO_3$, chemical quality.

Apparatus

- Water-cooled diamond saw.
- Migration set-up: One design (see Fig.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 2).
  - Catholyte reservoir: plastic box, 370 × 270 × 280 mm (length × width × height).
  - Plastic support: (see Figure 3).
  - Cathode: stainless steel plate (see Figure 3), about 0.5 mm thick.
  - Anode: stainless steel mesh or plate with holes (see Figure 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 ±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 ±0,1 mm.
- Ruler with a minimum scale of 1 mm.

Preparation of the test specimen. 6 cylinders from each **concrete I** (table 4) with Maximum Water/Rapid setting cement indicated by manufacturer, with a diameter of 100 mm and a length of 200 mm (EN 12390-1/4.3.1) shall be made in accordance to EN 12390-2.

The specimens shall be stored for 24 hours in the mould at climate (20ºC/95% HR). After demoulding the specimens shall be stored in water at 20±5 °C until testing. At an age of 28 days and 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: 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 chloride migration coefficient of concrete (D_{mig}) with the "Product" is compared to the chloride migration coefficient of the reference concrete at an age of 35 and 97 days*.*

Test procedure

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

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

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 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 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.

Migration test

- Turn on the power, with the voltage pre-set at 30 V, and record the initial current through each specimen.
- Adjust the voltage if necessary (as shown in Table 5). 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 5).
- Record the final current and temperature before terminating the test.

Measurement of chloride penetration depth

- Disassemble the specimen by following the reverse of the procedure in “Preparation of the test”. 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 5) to obtain seven depths (notes 1, 2 and 3). Measure the depth to an accuracy of 0,1 mm.

Note 1: 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 2: 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 3: 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 5).

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

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

Where:

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

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

D_{mig}: non-steady-state migration coefficient, m²/s;
z: absolute value of ion valence, for chloride, z = 1;
F: Faraday constant, F = 9,648 ×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 ≈ 0,07 N for OPC concrete;
c_0: chloride concentration in the catholyte solution, c_0 ≈ 2 N.

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

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

Where:
D_{mig}: non-steady-state migration coefficient, ×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.

The chloride migration coefficient of concrete (D_{mig}) with the "Product" is compared to the chloride migration coefficient of the reference concrete at an age 35 and 97 days.

Table 5. 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.

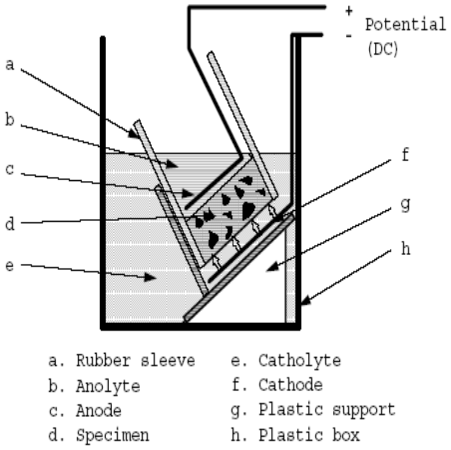


Figure 1

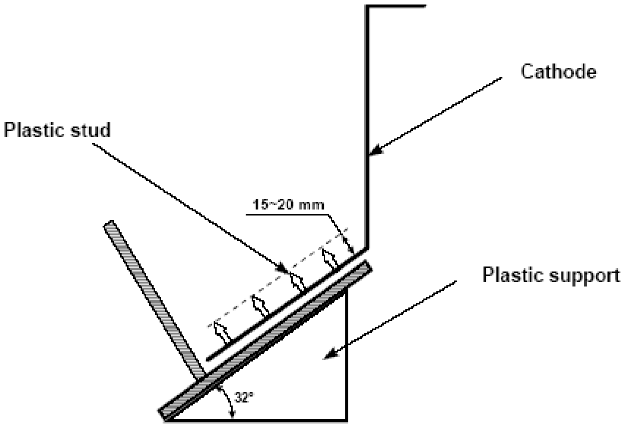


Figure 3: Plastic support and cathode

Figure 2: Stainless steel

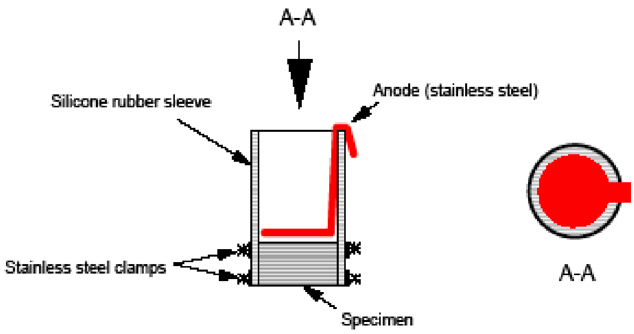


Figure 4: Rubber sleeve assembled with specimen, clamps and anode

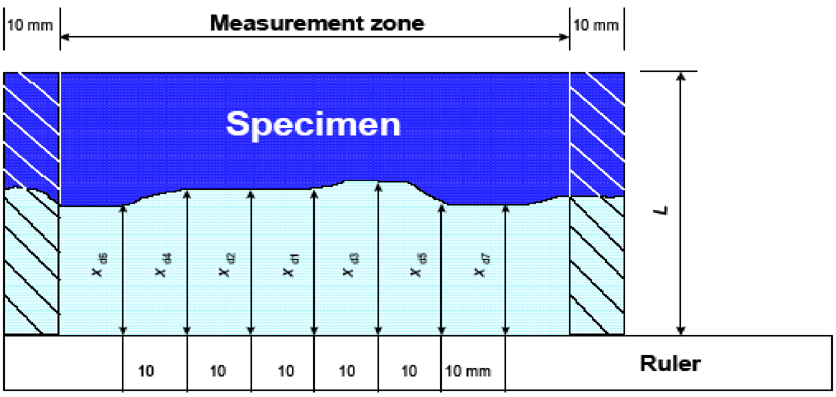


Figure 5: Illustration of measurement for chloride

A 1.8 Carbonation.

Method 1: Carbonation resistance–C_{dcr}.

The carbonation depth of concrete made with "Product" is measured according to *CEN/TS 12390-10*. The resistance of carbonation depth has to be tested on 3 prisms (40 mm x 40 mm x 160 mm) with aggregates according to EN 12620.

The carbonation resistance shall be tested on **concrete II** (table 4). If the consistence of this new fresh concrete/mortar varied significantly with the reference fresh concrete/mortar (EN 1015-3 or other methods) other ratio is allowed to obtain a similar consistence with the reference fresh concrete/mortar).

The specimens are prepared according to EN 196-1/4.4, 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 CO_2 content (commonly 350 to 450 p.p.m.). (CEN/TS 12390-10, Annex A).

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 "Product" is compared to data according to Annex 2.

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

$$d_C = d_0 + v_C \cdot \sqrt{t_C} \text{ expressed in mm / } \sqrt{d}$$

with:

d_c = carbonation depth (mm)

t_c = duration of carbonation (days)

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

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.

Method 2: Relative Carbonation resistance – C_{rcr}.

The carbonation resistance of concrete made with "Product" is measured according to CEN/TS 12390-10. The carbonation resistance shall be tested on 3 samples of **concrete IIIa** (table 4) and 3 samples of **concrete IIIb** (table 4). If the consistence of this new fresh concrete/mortar varied significantly with the reference fresh concrete/mortar (EN 1015-3 or other methods) other ratio is allowed to obtain a similar consistence with the reference fresh concrete/mortar).

Due to the very early setting time of some formula, the addition of a retarding admixture makes the preparation of the samples easier. When used, the nature and the dosage of retarding admixture shall be given in the ETA.

Concrete prisms are stored outdoor without curing under a ventilated shelter or in a carbonation chamber containing a CO_2 content close to the local normal climate (CEN/TS 12390-10, Annex B).

Measurements of carbonation depth shall be performed after 182 days for the granting of the ETA. It is recommended to continue the tests on the same samples after 273, 365, 547 and 730 days in order to verify the obtained results after 182 days and improve the knowledge.

The carbonation resistance of the concrete with "Product" is compared to the carbonation resistance of the reference concrete.

Note: For the assessment of the carbonation resistance for the "Product" the carbonation depth shall be determined to a test age of 182 days. The test shall be repeated after 2 years to get data of the concrete with the "Product". The results shall be recorded and evaluated.

A1.9 Freeze-thaw resistance without de-icing agent

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

The freeze-thaw resistance of concrete with the "Product" shall be determined according to CEN/TS 12390-9/6 ("cube procedure"). The freeze-thaw resistance ("cube procedure") shall be tested on 3 samples of **concrete IV** (table 4). If the consistence of this new fresh concrete varied significantly with the reference fresh concrete (EN 1015-3 or other methods) other ratio is allowed to obtain a similar consistence with the reference fresh concrete/mortar).

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

Furthermore the compressive strength 3 samples of **concrete IV** (table 4) shall be determined according to EN 12390-3 after 28 days. The specimens are immersed in water after demoulding until the age of 7 days. Afterwards the specimens are stored in climate 20/65. The scaling after 100 freeze-thaw-cycles (Cube-procedure) shall be given in the ETA.

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

The freeze-thaw resistance of concrete with the "Product" shall be determined according to CEN/TS 12390-9/7 ("CF-Procedure"). The internal structural damage shall be determined according to CEN/TR 15177/9.

The freeze-thaw resistance ("CF-Procedure") shall be tested on 3 samples of **concrete composition V** (table 4. If the consistence of this new fresh concrete/mortar varied significantly with the reference fresh concrete (EN 1015-3 or other methods) other ratio is allowed to obtain a similar consistence with the reference fresh concrete).

The compressive strength shall be determined according to EN 12390-3 after 28 days. The specimens are immersed in water after demoulding until the age of 7 days. Afterwards the specimens are stored in climate 20/65.

The relative dynamic modulus of elasticity (RDM) and scaling shall be measured after 0, 4, 10, 16, 22 and 28 freeze-thaw cycles. The scaling and the relative dynamic modulus of elasticity (RDM) after 28 freeze-thaw cycles (CF-procedure) shall be given in the ETA.

Method 3: Freeze-thaw resistance (Beam-Procedure) - FT_{beam}. T

he freeze-thaw resistance of concrete with the "Product" shall be determined according to the reference method in CEN/TR15177/7 – Internal structural damage ("Beam test"). The freeze-thaw resistance ("Beam test") shall be tested on 3 samples of **concrete IIIa** (table 4).

For the freeze-thaw resistance–internal damage according to CEN/TR15177/7 the relative dynamic modulus of elasticity (RDM) shall be measured after 7, 14, 28 and 56 freeze-thaw cycles. The relative dynamic modulus of elasticity (RDM) after 56 freeze-thaw cycles (Beam-procedure) shall be given in the ETA.

A 1.10 Freeze-thaw and de-icing salt resistance

Method 1: Freeze-thaw and de-icing resistance (CDF-Procedure) - FTS_{CDF}.

The freeze-thaw and de-icing salt resistance of concrete with the "Product" shall be determined according to CEN/TS 12390-9/7 ("CDF- Procedure"). Furthermore the internal structural damage shall be determined according to CEN/TR 15177/9.

The freeze-thaw resistance with de-icing salt ("CDF-Procedure") shall be tested on 3 samples of **concrete composition VI** (table 4). If the consistence of this new fresh concrete/mortar varied significantly with the reference fresh concrete/mortar (EN 1015-3 or other methods) other ratio is allowed to obtain a similar consistence with the reference fresh concrete/mortar).

Furthermore the compressive strength 3 samples of **concrete VI** (table 4) shall be determined according to EN 12390-3 after 28 days. The specimens are immersed in water after demoulding until the age of 7 days. Afterwards the specimens are stored in normal climate 20ºC/65%HR.

The air void parameter shall be determined according to EN 480-11 on **concrete VI** (table 4).

The relative dynamic modulus of elasticity (RDM) and scaling shall be measured after 0, 4, 6, 14, and 28 freeze-thaw cycles. The scaling after 28 freeze-thaw cycles (CDF-procedure) shall be given in the ETA.

Method 2: Freeze-thaw and de-icing resistance (Slab-Procedure) - FT_{slab}.

The freeze-thaw and de-icing salt resistance of concrete with "Product" shall be determined according to CEN/TS 12390-9/5 ("Slab test"). Furthermore the internal structural damage shall be determined according to CEN/TR 15177/8.

The freeze-thaw and de-icing salt resistance (“slab test”) shall be tested on 3 samples of **concrete IIIa** (table 4)

For the freeze-thaw and de-icing salt resistance according to CEN/TS 12390-9/5 and CEN/TR15177/8 the relative dynamic modulus of elasticity (RDM) and scaling shall be measured after 7, 14 and 28 freeze-thaw cycles. The scaling after 28 freeze-thaw cycles (Slab-procedure) shall be given in the ETA.

Table 4. Resume of the dosification of each type of concrete used in this EAD

<table>
<tr><th>Concrete Type</th><th>Composition</th><th>Aggregates size distribution (EN 12620)</th></tr>
<tr><td>Concrete I</td><td>Rapid setting cement Product 320±1kg/m³
Aggregates ……..±1 kg/m³
W/C=0,6 (or others)</td><td><table><tr><td>Size [mm]</td><td>0,25</td><td>0,5</td><td>1</td><td>2</td><td>4</td><td>8</td><td>16</td></tr><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></table></td></tr>
<tr><td>Concrete II</td><td>Rapid setting cement Product 450±2 g
Aggregates 1350±5 g
W=225±1g (or others)</td><td><table><tr><td>Size [mm]</td><td>0,25</td><td>0.5</td><td>1</td><td>2</td><td>4</td><td>8</td></tr><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></table></td></tr>
<tr><td>Concrete IIIa</td><td>Rapid setting cement Product 350±2 kg/m³
Aggregates ……±5 kg/m³
W/C=0,5 (or others)</td><td rowspan="2"><table><tr><td>Size [mm]</td><td>0,125</td><td>0,25</td><td>0,5</td><td>1</td><td>2</td><td>4</td><td>8</td><td>16</td><td>32</td></tr><tr><td>Passing (%) mass]</td><td>5</td><td>9</td><td>14</td><td>20</td><td>30</td><td>43</td><td>62</td><td>89</td><td>100</td></tr></table></td></tr>
<tr><td>Concrete IIIb</td><td>Cement CEM I 52.5R 350±2 kg/m³
Aggregates ……±5 kg/m³
W/C=0,5 (or others)</td></tr>
<tr><td>Concrete IV</td><td>Rapid setting cement Product 300±2 kg/m³
Aggregates ……±5 kg/m³
W/C=0,6 (or others)</td><td><table><tr><td>Size [mm]</td><td>0,125</td><td>0,25</td><td>0,5</td><td>1</td><td>2</td><td>4</td><td>8</td><td>16</td><td>32</td></tr><tr><td>Passing (%) mass]</td><td>1,5*)</td><td>5</td><td>23</td><td>35</td><td>45</td><td>56</td><td>70</td><td>85</td><td>100</td></tr></table></td></tr>
<tr><td>Concrete V</td><td>Rapid setting cement Product 320±2 kg/m³
Aggregates ……±5 kg/m³
W/C=0,5 (or others)</td><td rowspan="2"><table><tr><td>Size [mm]</td><td>0,25</td><td>0,5</td><td>1</td><td>2</td><td>4</td><td>8</td><td>16</td></tr><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></table></td></tr>
<tr><td>Concrete VI</td><td>Rapid setting cement Product 320±2 kg/m³
Aggregates ……±5 kg/m³
Concrete with air entraining agent. (The air content of the fresh concrete shall be 4,5 0,5 Vol.-%.),
W/C=0,5 (or others)</td></tr>
</table>

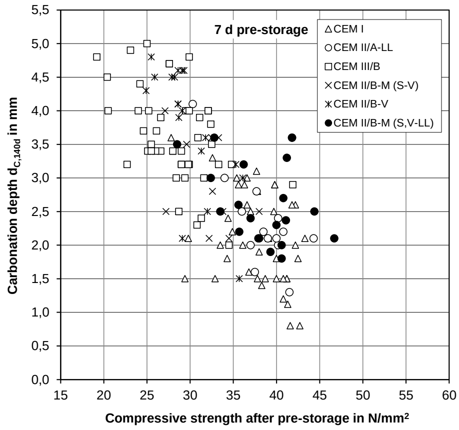
ANNEX B. EVALUATION OF THE CARBONATION RESISTANCE - C_{DCR}

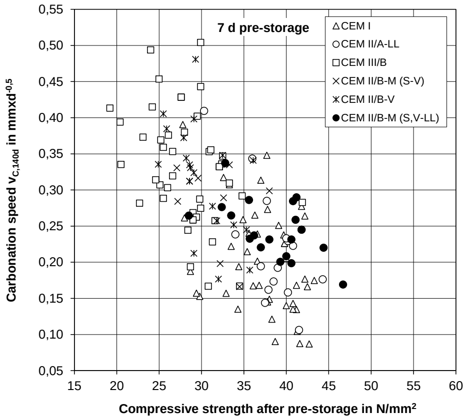
Carbonation test on concrete (w/c = 0,50) - **7** days pre-storage

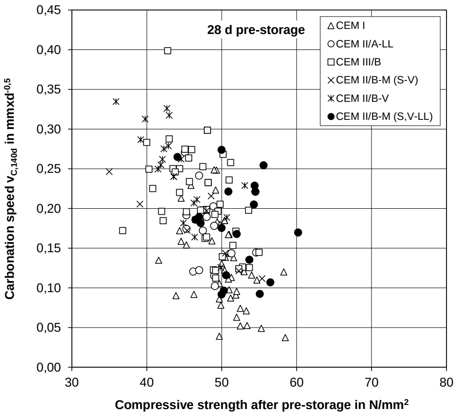
		f_C in N/mm²			Carbonation depth in mm								$F_{C,P}^{-0,5}$ in $N^{-0,5}$ x mm	Carbo. speed in mm / $d^{0,5}$	
		Pre-st	35 d	140 d	14 d	28 d	56 d	98 d	140 d	1 a	2 a	5 a		$v_{C,140d}$	$v_{C,5a}$
CEM II/B-M (S, V-LL)															
	min	28,5	51,2	50,8	0,2	0,4	1,0	1,5	1,8	3,1	3,7	6,8	0,146	0,169	0,147
	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
		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

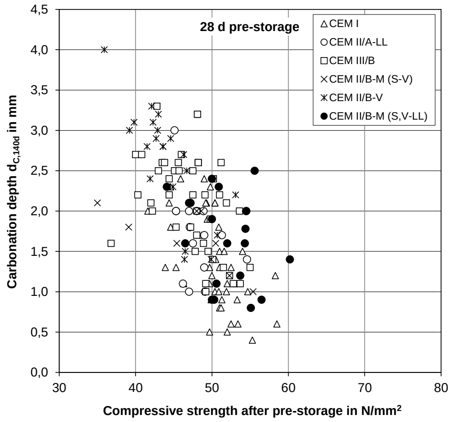
Carbonation test on concrete (w/c = 0,50) - **28** days pre-storage

		f_C in N/mm²			Carbonation depth in mm								$F_{C,P}^{-0,5}$ in $N^{-0,5}$ x mm	Carbo. speed in mm / $d^{0,5}$	
		Pre-st	35 d	140 d	14 d	28 d	56 d	98 d	140 d	1 a	2 a	5 a		$v_{C,140d}$	$v_{C,5a}$
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









Please note that the given diagrams are only valid with the given concrete composition other composition are not allowed.