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## Calcium aluminate cement - Composition, specifications and conformity criteria

Ciment d'aluminates de calcium - Composition, spécifications et critères de conformité

Tonerdezement - Zusammensetzung, Anforderungen und Konformitätskriterien

This European Standard was approved by CEN on 22 July 2005.

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This European Standard exists in three official versions (English, French, German). A version in any other language made by translation under the responsibility of a CEN member into its own language and notified to the Central Secretariat has the same status as the official versions.

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## Foreword

This European Standard (EN 14647:2005) has been prepared by Technical Committee CEN/TC 51 "Cement and building limes", the secretariat of which is held by IBN/BIN.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by April 2006, and conflicting national standards shall be withdrawn at the latest by July 2007.

This European Standard has been prepared under a mandate given to CEN by the European Commission and the European Free Trade Association, and supports essential requirements of EU Directive(s).

For relationship with EU Directive(s), see informative Annex ZA, which is an integral part of this European Standard.

The requirements in this European Standard are based on the results of tests on cement in accordance with EN 196-1, -2, -3, -5, -6, and -7. The scheme for the evaluation of conformity of calcium aluminat cement is specified in EN 197-2.

According to the CEN/CENELEC Internal Regulations, the national standards organizations of the following countries are bound to implement this European Standard: Austria, Belgium, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Slovakia, Slovenia, Spain, Sweden, Switzerland and United Kingdom.

## Introduction

Calcium aluminate cement was developed during the latter stages of the nineteenth century as an alternative to calcium silicate cement (Portland cement) to prevent structural elements from serious sulfate attack.

Whilst it is suitable for sulfate resistance it was also found to be exceptionally rapid hardening and resistant to high temperatures. It was this rapid hardening property that led to more general use particularly in precast applications.

The hydration of calcium aluminate cement is substantially different from that of Portland cement in that the calcium aluminate hydrates formed depend upon the temperature at which hydration takes place. At low and normal temperatures (less than 40 °C) the hydration process leads to a temporarily high strength. This situation can last for several days or many years, depending mainly upon temperature and humidity, before stable long term hydrates develop. This process, known as conversion, is inevitable. It is the result of a phase transition in the hardened paste of cement and is accompanied by a decrease in strength to a minimum stable level.

Misunderstanding of this conversion process and unsuccessful attempts to maintain the temporary high strength led to failures in several countries during the 1960's and 1970's. In one of the reported failures, the strength of concrete, made with calcium aluminate cement, was reduced even further as a result of chemical attack. Chemical resistance is reduced when porosity of concrete is increased by a high water/cement ratio and conversion. As a result, calcium aluminate cement has been, and remains, excluded from the list of cements permitted in structural concretes in some countries.

Guidance for the correct use of this cement is given in Annex A. It includes a method which allows the long term strength, i.e. after conversion, to be predicted.

NOTE 1 Calcium aluminate cement can be produced in a blastfurnace, using a process of reductive fusion (a method used in Germany until the 1980's) but the cement will have a high level of sulfides which would exclude it from this European Standard.

NOTE 2 Calcium aluminate cement has previously been known by several alternative names in different countries, e.g.

- high alumina cement;
- aluminous cement;
- high alumina melted cement.

## 1 Scope

This European Standard gives a general definition of calcium aluminate cement and its composition. It includes requirements for the mechanical, physical and chemical properties and also states the conformity criteria and the related rules.

Calcium aluminate cement used as a constituent material of formulated mixes for specific applications (e.g. dry mixes) is outside the scope of this European Standard.

NOTE Guidance for the correct use of calcium aluminate cement in concrete and mortars is given in Annex A.

## 2 Normative references

The following referenced documents are indispensable for the application of this European Standard. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

EN 197-2:2000, *Cement — Part 2: Conformity evaluation*

EN 196-1, *Methods of testing cement — Part 1: Determination of strength*

EN 196-2, *Methods of testing cement — Part 2: Chemical analysis of cement*

EN 196-3, *Methods of testing cement — Part 3: Determination of setting time and soundness*

EN 196-7, *Methods of testing cement — Part 7: Methods of taking and preparing samples of cement*

## 3 Terms and definitions

For the purposes of this European Standard, the following terms and definitions apply.

### 3.1

#### **autocontrol testing**

continual testing by the manufacturer of cement spot samples taken at the point(s) of release from the factory/depot

### 3.2

#### **control period**

period of production and dispatch identified for the evaluation of the autocontrol test results

### 3.3

#### **characteristic value**

value of a required property outside of which lies a specified percentage, the percentile  $P_k$  of all the values of the population

### 3.4

#### **specified characteristic value**

characteristic value of a mechanical, physical or chemical property which in the case of an upper limit is not to be exceeded or in the case of a lower limit is, as a minimum, to be reached

### 3.5

#### **single result limit values**

value of a mechanical, physical or chemical property which - for any single test result - in the case of an upper limit is not to be exceeded or in the case of a lower limit is, as a minimum, to be reached

**3.6**

**allowable probability of acceptance**

**CR**

for a given sampling plan, the allowed probability of acceptance of cement with a characteristic value outside the specified characteristic value

**3.7**

**sampling plan**

specific plan which states the (statistical) sample size(s) to be used, the percentile  $P_k$  and the allowable probability of acceptance  $CR$

**3.8**

**spot sample**

sample taken at the same time and from one and the same place, relating to the intended tests. It can be obtained by combining one or more immediately consecutive increments (see EN 196-7)

## **4 Calcium aluminate cement (CAC)**

Calcium aluminate cement is a hydraulic binder i.e. it is a finely ground inorganic material which, when mixed with water, forms a paste which sets and hardens by means of hydration reactions and processes and which, after the hydration process has produced stable hydrated phases after conversion, retains its strength and stability.

Cement conforming to this European Standard shall, when appropriately batched and mixed with aggregate and water, be capable of producing concrete or mortar which retains its workability for a sufficient time and shall after defined periods attain specified strength levels and also possess long term volume stability.

The main component is monocalcium aluminate ( $\text{CaO}\cdot\text{Al}_2\text{O}_3$ ). Other mineralogical compounds include calcium alumino-ferrites, dicalcium silicate, and calcium silico-aluminate or gehlenite.

Hydraulic hardening of calcium aluminate cement is primarily due to the hydration of monocalcium aluminate, but other chemical compounds may also participate in the hardening process.

Calcium aluminate cement consists of individual small grains of calcium aluminate clinker statistically homogeneous in composition resulting from quality assured production and material handling processes. The link between these production and material handling processes and the conformity of calcium aluminate cement to this European Standard is elaborated in EN 197-2.

## **5 Constituents**

### **5.1 Calcium aluminate cement clinker**

Calcium aluminate cement clinker is produced by fusing or sintering a precisely specified mixture of aluminous and calcareous material.

## 5.2 Grinding aids

Grinding aids are chemical substances or proprietary products added to the calcium aluminate cement clinker during the grinding process to enhance the efficiency of the process. The total quantity of grinding aid on a dry basis shall not exceed 0,2 % by mass of the cement. Grinding aids shall not promote corrosion of reinforcement or impair the properties of the cement or of concrete and mortar made with the cement.

## 6 Cement type and composition

Except for grinding aids that may be used in manufacture, as stated in 5.2, calcium aluminate cement shall be composed of only calcium aluminate cement clinker.

## 7 Mechanical, physical and chemical requirements

### 7.1 Compressive strength

The compressive strength of calcium aluminate cement shall not be less than 18,0 MPa at 6 h and 40,0 MPa at 24 h, when tested in accordance with EN 196-1 at 6 h and 24 h (see also Table 1) under the following conditions:

- composition of the mortar shall be 1 350 g of CEN Standard sand, 500 g of calcium aluminate cement, and 200 g of water, i.e. a water/cement ratio of 0,40;
- all specimens shall be demoulded after 6 h  $\pm$  15 min;
- specimens to be tested at 6 h shall be tested immediately after demoulding;
- specimens to be tested at 24 h shall be stored in water after demoulding, and tested at 24 h  $\pm$  15 min.

### 7.2 Initial setting time

The initial setting time, determined in accordance with EN 196-3, shall not be less than 90 min (see also Table 1).

Other methods than EN 196-3 may be used provided that they give results correlated and equivalent to those obtained with EN 196-3.

**Table 1 — Mechanical and physical requirements given as characteristic values**

Compressive strength (MPa)		Initial setting time (min)
at 6 h	at 24 h	
$\geq 18,0$	$\geq 40,0$	$\geq 90$

NOTE 1 Calcium aluminate cements are very rapid hardening so 28 day strengths at 20 °C are not relevant. It is traditional to test conformity for strength at these early ages.

NOTE 2 Values obtained from these tests should not be used for design purposes for concrete. An explanation of the strength development of calcium aluminate cement concretes and a method for predicting their minimum long term strength is given in Annex A.

### 7.3 Chemical requirements

The properties of calcium aluminate cement shall conform to the requirements listed in Table 2 when tested in accordance with the European Standard referred to.

NOTE Some European countries have regulations for the content of water-soluble hexavalent chromium (see Annex B).

**Table 2 — Chemical requirements given as characteristic values**

Property	Test reference	Requirements <sup>a</sup>
Alumina content (as Al <sub>2</sub> O <sub>3</sub> )	EN 196-2	35 % ≤ Al <sub>2</sub> O <sub>3</sub> ≤ 58 %
Sulfide content (as S <sup>-2</sup> )	EN 196-2	≤ 0,10 %
Chloride content	EN 196-2	≤ 0,10 %
Alkali content <sup>b</sup>	EN 196-2	≤ 0,4 %
Sulfate content (as SO <sub>3</sub> )	EN 196-2	≤ 0,5 %
<sup>a</sup> Requirements are given as percentage by mass of the final cement. <sup>b</sup> Expressed as Na <sub>2</sub> O equivalent (Na <sub>2</sub> O + 0,658 K <sub>2</sub> O).		

## 8 Standard designation

Calcium aluminate cement conforming to this European Standard shall be identified by:

Calcium aluminate cement EN 14647 CAC

The notation CAC covers definition (Clause 4), composition (Clauses 5 and 6) and requirements (Clauses 7 and 9).

NOTE 1 European cements are normally identified by type and a figure indicating the strength class. With calcium aluminate cement, care must be taken when assessing strength, due to the difference that is seen in cement hydration and hence strength development. Consequently it is normal that the designation of calcium aluminate cement does not refer to a strength class.

NOTE 2 A more extensive description of the strength development of calcium aluminate cement in concrete and mortar is given in Annex A.

## 9 Conformity criteria

### 9.1 General requirements

Conformity of calcium aluminate cement to this European Standard shall be continually evaluated on the basis of testing of spot samples. The properties, test methods and the minimum testing frequencies for the autocontrol testing by the manufacturer are specified in Table 3. Concerning testing frequencies for cement not being dispatched continuously and other details, see EN 197-2.

For certification of conformity by an approved certification body, conformity of cement with this European Standard shall be evaluated in accordance with EN 197-2.

NOTE This European Standard does not deal with acceptance inspection at delivery.

**Table 3 — Properties and test methods and minimum testing frequencies for the autocontrol testing by the manufacturer and the statistical assessment procedure**

Property	Test method <sup>a b</sup>	Minimum testing frequency		Statistical assessment procedure	
		Routine situation	Initial period	Inspection by	
				variables <sup>d</sup>	attributs <sup>e</sup>
Strength	EN 196-1	2/week	4/week	x	
Initial setting time	EN 196-3	2/week	4/week	x	
Alumina content	EN 196-2	2/month	1/week		x
Chloride content	EN 196-2	2/month <sup>c</sup>	1/week		x
Alkali content	EN 196-2	1/month	1/week		x
Sulfate content	EN 196-2	1/month	1/week		x
Sulfide content	EN 196-2	1/month	1/week		x

<sup>a</sup> Where allowed in the relevant part of EN 196, other methods than those indicated may be used provided they give results correlated and equivalent to those obtained with the reference method.

<sup>b</sup> Methods used to take and prepare samples shall be in accordance with EN 196-7.

<sup>c</sup> When none of the test results within a period of 12 months exceeds 50 % of the characteristic value, the frequency may be reduced to one per month.

<sup>d</sup> If the data are not normally distributed, then the method of assessment may be decided on a case by case basis.

<sup>e</sup> If the number of samples is at least one per week during the control period, the assessment may be made by variables.

## 9.2 Conformity criteria and evaluation procedure

### 9.2.1 General

Conformity of calcium aluminate cement with this European Standard is assumed if the conformity criteria specified in 9.2.2 and 9.2.3 are met. Conformity shall be evaluated on the basis of continual sampling using spot samples taken at the point of release and on the basis of the test results obtained on all autocontrol samples taken during the control period.

### 9.2.2 Statistical conformity criteria

#### 9.2.2.1 General

Conformity shall be formulated in terms of a statistical criterion based on:

- specified characteristic values for mechanical, physical and chemical properties as given in 7.1, 7.2 and 7.3;
- percentile  $P_k$ , on which the specified characteristic value is based, as given in Table 4;
- allowable probability of acceptance  $CR$ , as given in Table 4.

Table 4 — Required values for  $P_k$  and  $CR$ 

	Mechanical requirements		Physical and chemical requirements
	6 h strength (Lower limit)	24 h strength (Lower limit)	
The percentile $P_k$ on which the characteristic value is based	10 %	5 %	10 %
Allowable probability of acceptance $CR$	5 %		

NOTE Conformity evaluation by a procedure based on a finite number of test results can only produce an approximate value for the proportion of results outside the specified characteristic value in a population. The larger the sample size (number of test results), the better the approximation. The selected probability of acceptance  $CR$  controls the degree of approximation by the sampling plan.

Conformity with the requirements of this European Standard shall be verified either by variables or by attributes as described in 9.2.2.2 and 9.2.2.3 as specified in Table 3.

The control period shall be 12 months.

#### 9.2.2.2 Inspection by variables

For this inspection the test results are assumed to be normally distributed.

Conformity is verified when the following Equation(s) (1) and (2), as relevant, are satisfied:

$$\bar{x} - k_A \times s \geq L \quad (1)$$

and

$$\bar{x} + k_A \times s \leq U \quad (2)$$

where

$\bar{x}$  is the arithmetic mean of the totality of the autocontrol test results in the control period;

$s$  is the standard deviation of the totality of the autocontrol test results in the control period;

$k_A$  is the acceptability constant;

$L$  is the specified lower limit given in Tables 1 and 2 referred to in 7.1 and 7.3;

$U$  is the specified upper limit given in Table 2 referred to in 7.3.

The acceptability constant  $k_A$  depends on the percentile  $P_k$  on which the characteristic value is based, on the allowable probability of acceptance  $CR$  and the number  $n$  of the test results. Values of  $k_A$  are listed in Table 5.

Table 5 — Acceptability constant  $k_A$ 

Number of test results n	$k_A^a$	
	for $P_K = 5\%$ (24 h strength, lower limit)	for $P_K = 10\%$ (other properties)
20 to 21	2,40	1,93
22 to 23	2,35	1,89
24 to 25	2,31	1,85
26 to 27	2,27	1,82
28 to 29	2,24	1,80
30 to 34	2,22	1,78
35 to 39	2,17	1,73
40 to 44	2,13	1,70
45 to 49	2,09	1,67
50 to 59	2,07	1,65
60 to 69	2,02	1,61
70 to 79	1,99	1,58
80 to 89	1,97	1,56
90 to 99	1,94	1,54
100 to 149	1,93	1,53
150 to 199	1,87	1,48
200 to 299	1,84	1,45
300 to 399	1,80	1,42
> 400	1,78	1,40

NOTE Values given in this table are valid for  $CR = 5\%$ .

<sup>a</sup> Values of  $k_A$  valid for intermediate values of n may also be used.

### 9.2.2.3 Inspection by attributes

The number  $c_D$  of test results outside the characteristic value shall be counted and compared with an acceptable number  $c_A$ , calculated from the number n of autocontrol test results and the percentile  $P_K$  as specified in Table 6.

Conformity is verified when the Equation (3) is satisfied:

$$c_D \leq c_A \quad (3)$$

The value of  $c_A$  depends on the percentile  $P_K$  on which the characteristic value is based, on the allowable probability of acceptance  $CR$  and on a number  $n$  of the test results. Values of  $c_A$  are listed in Table 6.

Table 6 — Values of  $c_A$ 

Number of test results $n^a$	$c_A$ for $P_K = 10\%$
20 to 39	0
40 to 54	1
55 to 69	2
70 to 84	3
85 to 99	4
100 to 109	5
110 to 123	6
124 to 136	7

NOTE Values given in this table are valid for  $CR = 5\%$ .

<sup>a</sup> If the number of test results is  $n < 20$  (for  $P_K = 10\%$ ) a statistically based conformity criterion is not possible. Despite this, a criterion of  $c_A = 0$  shall be used in cases where  $n < 20$ .

### 9.2.3 Single result conformity criteria

In addition to the statistical conformity criteria, conformity of test results to the requirements of this document requires that it shall be verified that each test result remains within the single result limit values specified in Table 7.

Table 7 — Limit values for single results

Property		Limit values for single results
Strength (MPa) lower limit value	6 h	15,0
	24 h	38,0
Initial setting time (min) lower limit value		75
Alumina content (%) <sup>a</sup>	lower limit value	33
	upper limit value	60
Sulfide content (%) <sup>a</sup> upper limit value		0,15
Chloride content (%) <sup>a</sup> upper limit value		0,10
Alkali content (%) <sup>a b</sup> upper limit value		0,5
Sulfate content (%) <sup>a</sup> upper limit value		0,6
<sup>a</sup> By mass of the final cement. <sup>b</sup> Expressed as Na <sub>2</sub> O equivalent (Na <sub>2</sub> O + 0,658 K <sub>2</sub> O).		

## Annex A (informative)

### Guidance for the use of calcium aluminate cement in concrete and mortar

#### A.1 Introduction

Calcium aluminate cement that is produced in conformity to this European Standard can be used, provided it is permitted by national regulations, in construction applications that require the special properties of concretes and mortars made with this cement. The purpose of this annex is to provide guidance for the use of calcium aluminate cement in concrete and mortar.

**NOTE** Applying this annex A does not imply compliance with provisions valid in the place of use of the CAC concrete.

To ensure that requirements of stability and durability are met, it is essential to take into account the conversion phenomenon. For design purpose, only strength after conversion shall be considered. As for any conventional concrete, final performance depends on water/cement ratio, aggregate type and grading, mix proportions, production and placement. Special care has to be taken on the impact of water/cement ratio on strength level after conversion.

For historical reasons, for structural use of calcium aluminate cement based concrete, a total water/cement ratio not greater than 0,40 (corresponding to an effective water/cement ratio of about 0,33 to 0,36) is recommended to achieve satisfactory converted strength. At this level of water/cement ratio, when admixture is not used, the minimum cement content to ensure a paste volume compatible with a good workability is 400 kg/m<sup>3</sup>.

However, any mix design should be chosen in order to meet strength and durability requirements for the intended application. For non-structural applications, it is possible to obtain appropriate converted strength and durability with a total water/cement ratio greater than 0,40.

For any use of calcium aluminate cement based concrete, converted strength shall always be estimated with appropriate procedure to ensure conformity with design specifications (see A.7). Furthermore proper attention should also be given to durability of concrete.

Calcium aluminate cement is not intended to be used as a general replacement for the common cements in EN 197-1. Its use will be in specialised areas which stem from its special properties:

- normal setting time but rapid hardening;
- resistance to temperature, abrasion and chemical attack;
- normal hardening rate in cold weather (see A.6.1).

If concrete is made in accordance with the principles given in this annex, it does not imply any conformity to national or international codes for design.

## A.2 Specific characteristics of calcium aluminate cement

### A.2.1 Hydration of calcium aluminate cement

As the main component of calcium aluminate cement is monocalcium aluminate, its hydration produces calcium aluminate hydrates and insoluble alumina trihydrate without liberating calcium hydroxide (portlandite). This means that CAC concrete has good resistance to many aggressive agents (see A.3.5 and A.6.3).

### A.2.2 Nature of the hydrates and conversion process

The following customary abbreviations are used:

A = Al<sub>2</sub>O<sub>3</sub>;

C=CaO;

H=H<sub>2</sub>O.

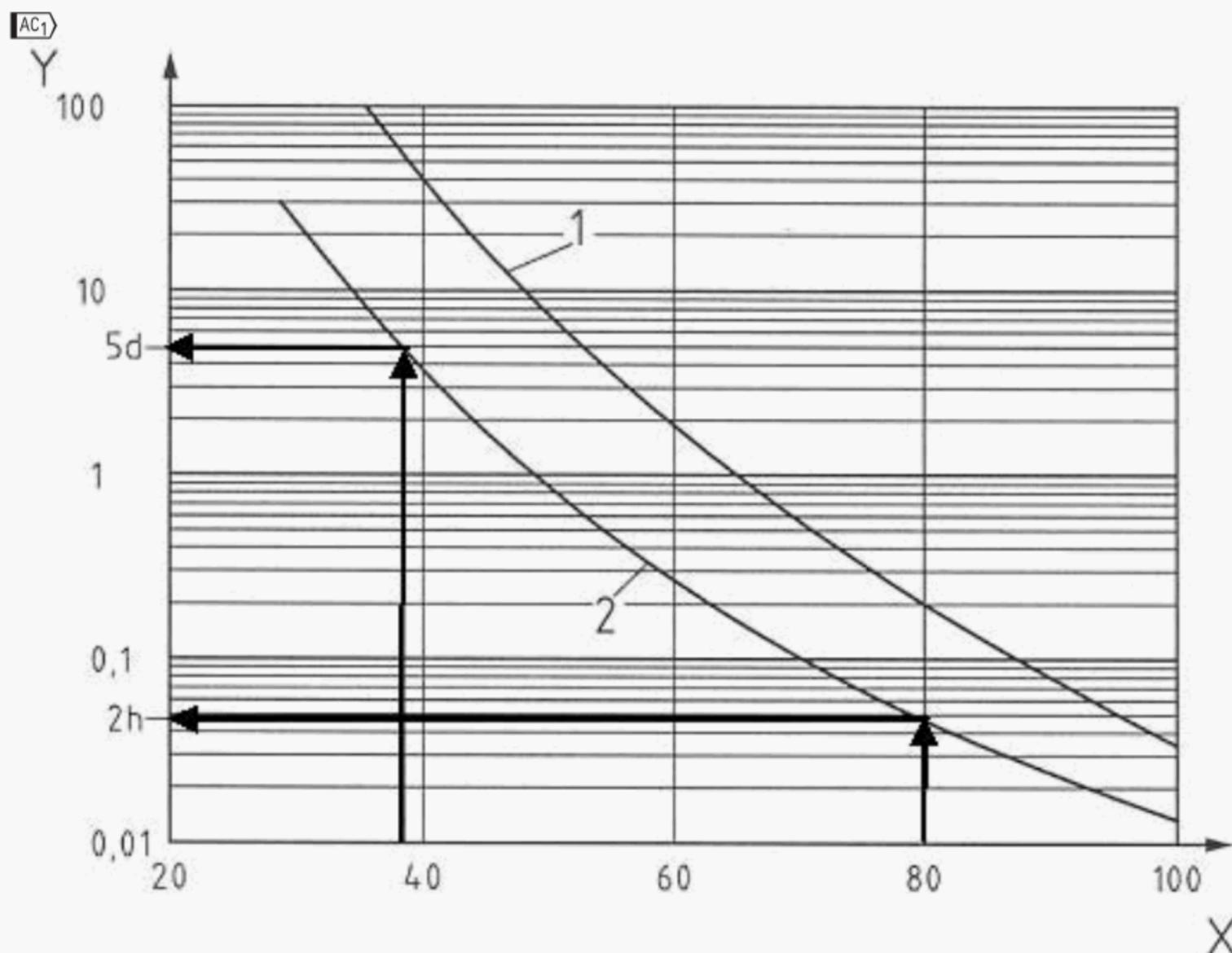
CAC hydration always starts with the formation of the metastable hexagonal hydrates CAH<sub>10</sub> and C<sub>2</sub>AH<sub>8</sub>. CAH<sub>10</sub> and C<sub>2</sub>AH<sub>8</sub> change with time to form the stable cubic hydrate, C<sub>3</sub>AH<sub>6</sub> and gibbsite AH<sub>3</sub>, following the reactions shown below:



This evolution, which is known as conversion is inevitable and irreversible, but the minimum strength level after conversion can be estimated. Complete conversion may take several years at 20 °C, but accelerates rapidly as temperature increases, as shown in Figure A.1, which gives two examples of the effect of temperature on the time taken to reach minimum strength after conversion. For example when concrete temperature is maintained above 80 °C, stable hydrates can be formed within only a few hours.

Because of differences in the hydrate densities, conversion is accompanied by an increase in the porosity. Therefore, the strength after conversion is significantly lower than that before conversion. This explains why the transient initial strength of CAC concrete may be higher than its long term stable strength (see A.3.4.). It is therefore recommended to keep the total W/C ratio not greater than 0,40 for the structural use of CAC. However meeting this specification does not preclude verifying that the mix design meets any other performance requirement.

Figure A.1 gives two examples of the effect of temperature on conversion. For this figure, the time to achieve conversion is defined by the time to reach minimum strength.



### Key

- 1 Samples were pre-cured for 24 h at 20°C and then cured at the given temperature under water.
- 2 Samples were placed directly under water (without pre-curing) at the given curing temperature.
- Y Time to reach minimum strength (days-log scale)
- X Curing Temperature (°C)

Figure A.1 – Time to reach minimum strength after conversion at different curing temperatures AC1

### A.2.3 Hydration in presence of lime

In presence of calcium hydroxide, the setting rate is strongly accelerated, hardening is slowed down, and final strengths are lowered.

Because of this sensitivity, precautions must be taken to ensure that lime or Portland based cement will not be mixed by accident when manufacturing concrete.

Mixes of calcium aluminate cement and Portland based cement and/or lime can be used however to produce rapid setting mixes (see A.8 [1]). These mixes are not considered in this annex and have to be specifically studied case by case.

## A.3 Hydraulic properties

### A.3.1 Setting time

In a range of temperature at around 28°C, an increase of the setting time may occur (see A.8 [1] and A.8 [2]). Generally this setting time anomaly is much less significant in site conditions than in laboratory conditions, where all the materials are maintained at a given temperature.

## A.3 Hydraulic properties

### A.3.1 Setting time

In a range of temperature at around 28°C, an increase of the setting time may occur (see A.8 [1] and A.8 [2]). Generally this setting time anomaly is much less significant in site conditions than in laboratory conditions, where all the materials are maintained at a given temperature.

### A.3.2 Specific properties of calcium aluminate cement pastes, mortars and concretes

Soundness measured according to EN 196-3 is less than the minimum sensitivity of the measuring device and for this reason there is no specification for soundness in this European Standard. In addition, the absence of significant quantities of dead burned lime, magnesia or sulfate, means that late expansion is not to be expected in calcium aluminate cement.

The total heat of hydration of calcium aluminate cement is in the range of 400 J/g to 500 J/g. It is liberated much more rapidly than with a Portland cement. A maximum temperature of 70 °C to 80 °C can be attained in mass concrete within 6 h.

The variation of the absolute volume of the paste due to hydrate formation is greater than for Portland cements (Le Chatelier contraction).

Usually, shrinkage in air, after setting, develops earlier than in Portland cement mortars and concretes, but attains very similar values at 28 days.

For these reasons, appropriate curing measures should be applied to prevent early cracking (see A.4.3)

### A.3.3 Protection of the reinforcement

The pH of the pore solution, around 12, together with the very low solubility of  $\text{Al}(\text{OH})_3$  in the pH range 4 to 11, lead to a satisfactory protection of the reinforcement provided that a dense structure of the hardened paste is achieved, and maintained after conversion. For this reason, it is recommended for structural applications, to keep the total W/C ratio not greater than 0,40 (see A.2.2).

In an aggressive environment (mainly: chloride, sulfide,  $\text{CO}_2$ ), compaction and the thickness of the concrete cover shall be sufficient to avoid a drop of the pH value near the reinforcement, which could lead to the loss of protection.

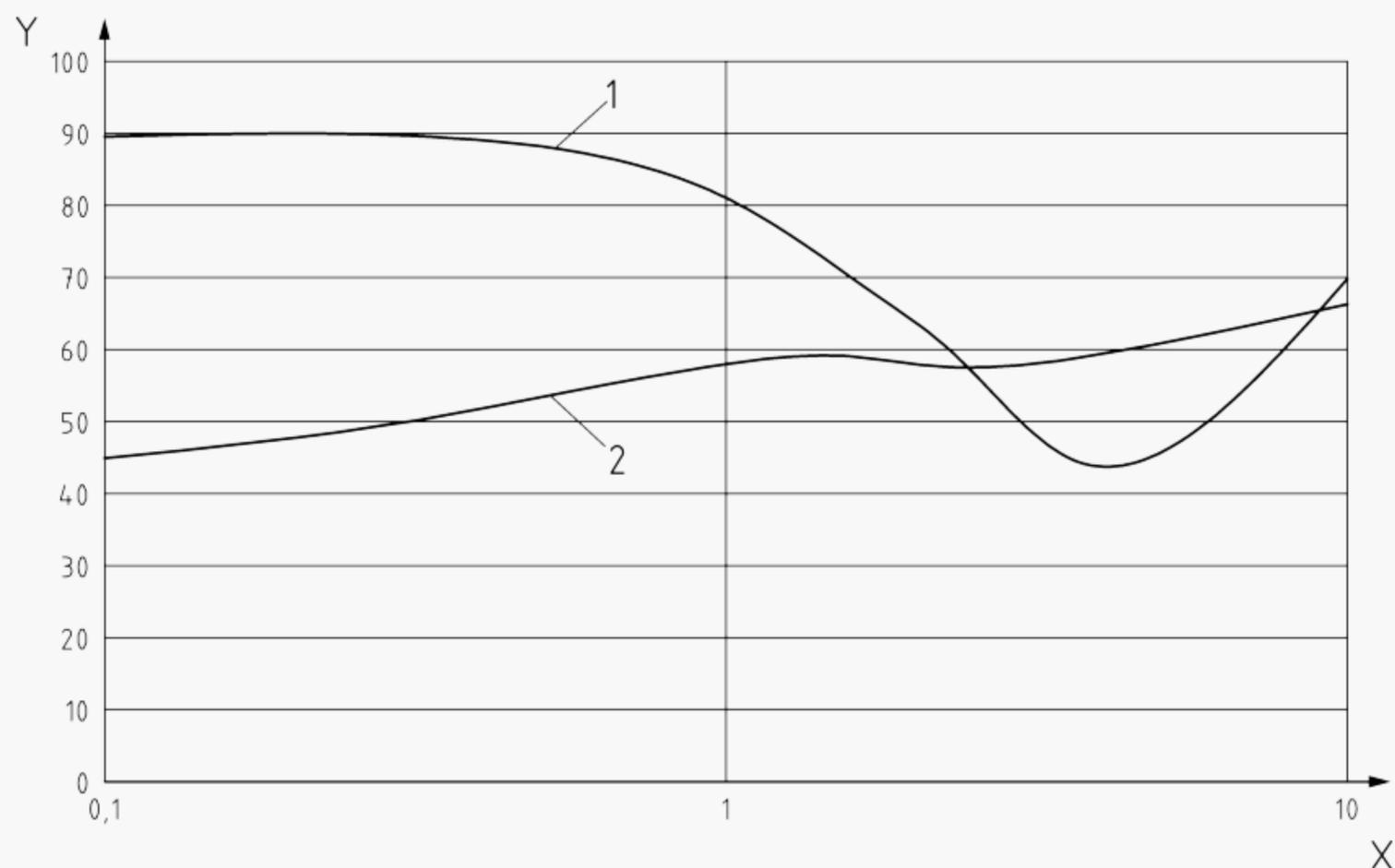
The recommended thickness of the concrete cover is as stated in Tables 4-2 of EN 1992-1-1:2004 (see A.8 [3]).

### A.3.4 Strength development

Owing to the conversion process described in A.2.2, strength develops differently when hydration occurs at low or high temperature. Figure A.2 illustrates these differences in strength development over a period of 10 years.

Concretes of small cross sections maintained at or around 20 °C remain in their metastable form for several years, showing very high strength. Over time, with the progression of the conversion process, strength will decrease to a minimum stable level, characteristic of the mix design. Once conversion is completed, the strength will remain stable, or even increase slightly if further hydration takes place.

In concrete structures with large cross section, in which a temperature of 75 °C can easily be reached, conversion takes place rapidly and the strength will remain stable over time.

**Key**

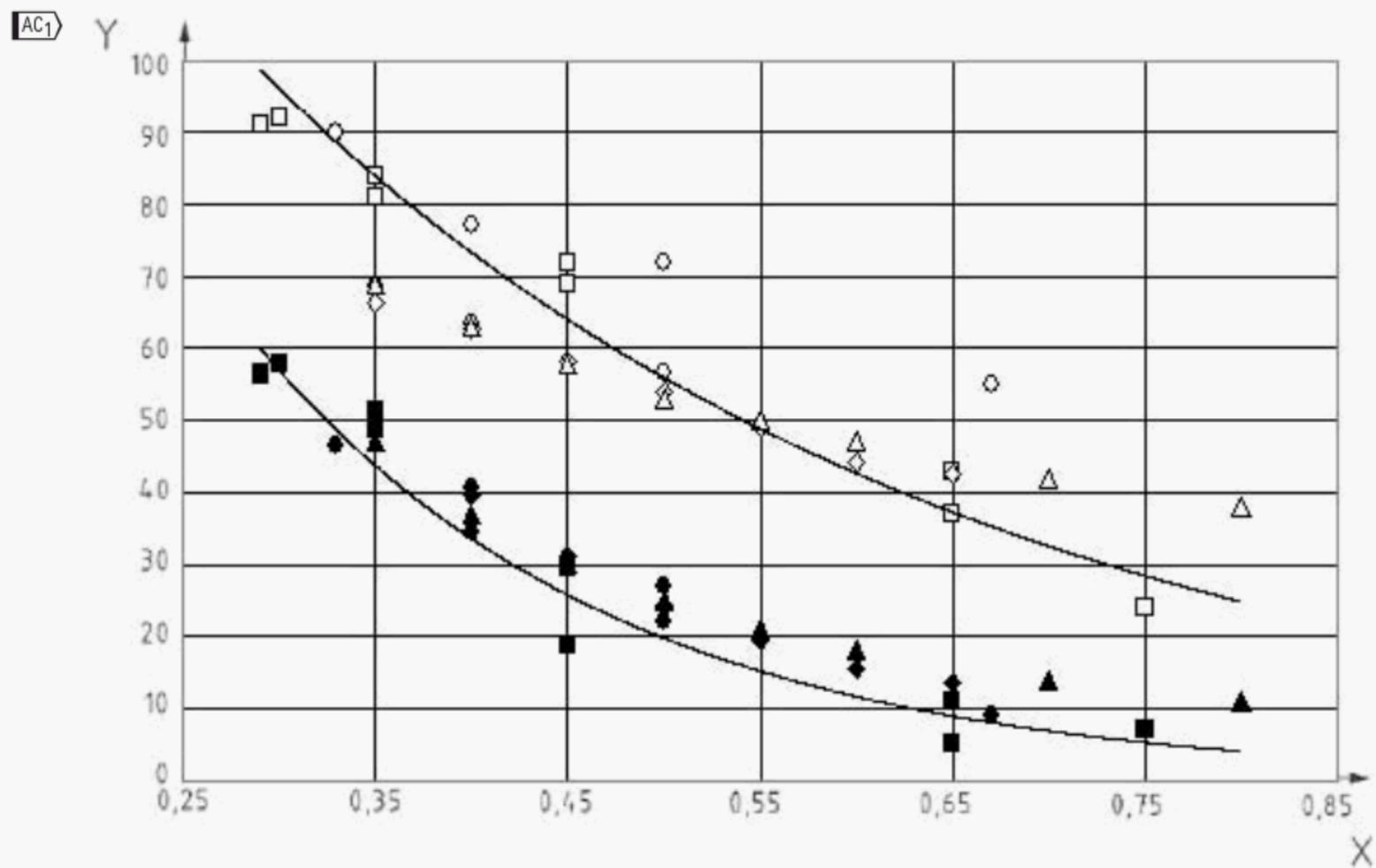
- 1 Initial hydration at 20 °C for 2 days, then protected outdoor conditions
- 2 Initial hydration at 70 °C for 2 days, then protected outdoor conditions
- Y Cube compressive strength (MPa)
- X Time in year (Log scale)

**Figure A.2 – Typical long term strength development  
(Total W/C = 0,40; cement content: 400 kg/m<sup>3</sup>)**

For design purposes, only the minimum strength after conversion must be considered and a method for estimating this minimum strength is given in A.7.

Figure A.3 shows the critical influence of the W/C ratio on the compressive strength level before and after conversion (A.8 [1] [2] [4] [5] [10] and [11]). It can be seen that converted strength cannot be estimated from the unconverted strength, since the ratio between the two is not constant. This is why the converted strength is the only relevant strength value for design purposes. As for any concrete, the specified W/C ratio should be adhered to during concrete production to achieve targeted properties. Figure A.3 shows the influence of a deviation from the specified W/C ratio.

Figure A.4 shows the influence of the W/C ratio on porosity of neat cement paste, before and after conversion (A.8 [12]). Because porosity plays a major role in durability of concrete, and increases with the W/C ratio, it is important to adhere to the specified W/C ratio to achieve both design strength and durability.



### Key

Y Compressive Strength on cubes (MPa)

X Total Water/Cement Ratio

○ George (1990) - Before conversion

● George (1990) - After conversion

□ Neville (1994) - Before conversion

■ Neville (1994) - After conversion

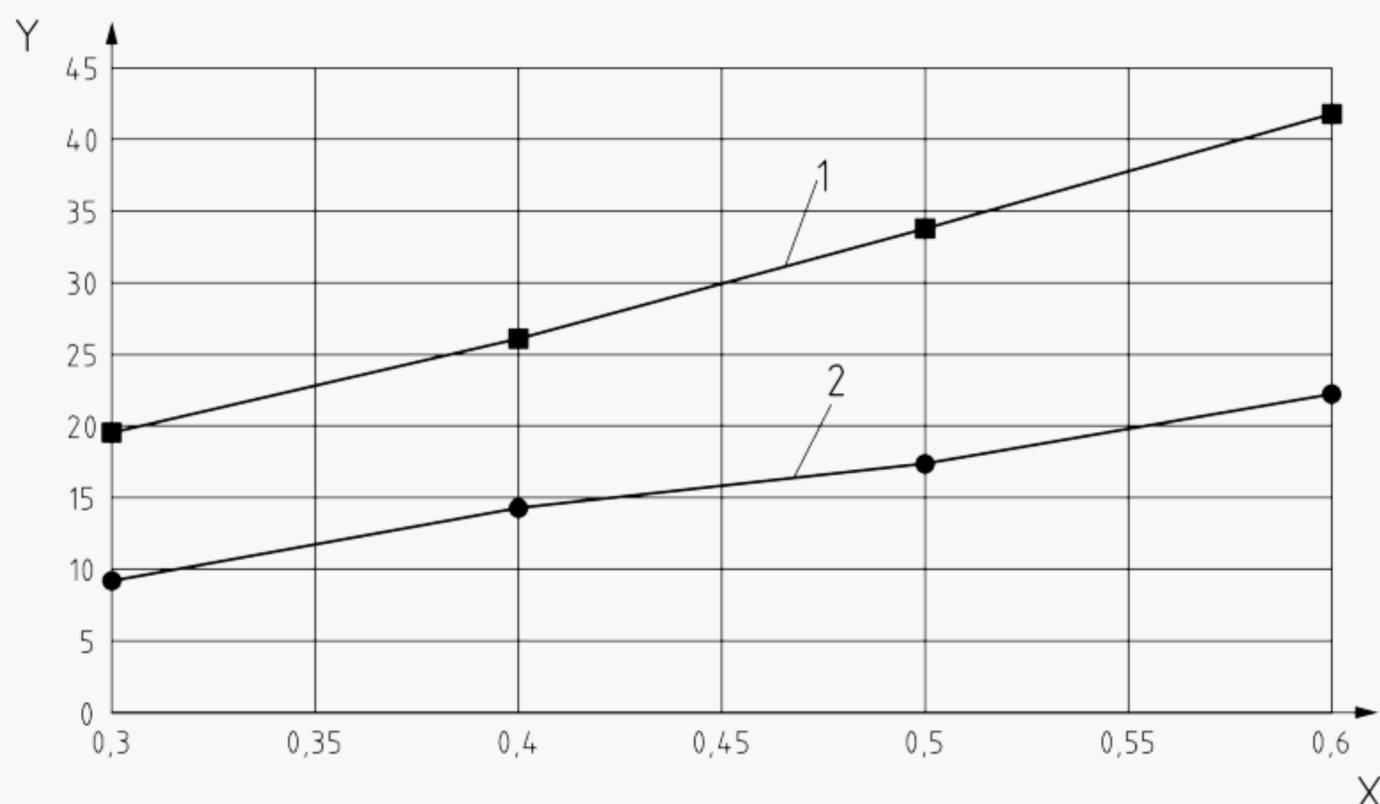
◇ Robson (1962) - Before conversion

◆ Robson (1962) - After conversion

△ BRE (1988) - Before conversion

▲ BRE (1988) - After conversion

Figure A.3 – Relation between total water/cement ratio and compressive strength of CAC concrete before and after conversion AC1



### Key

Y	Porosity by mercury intrusion (%)	1	Before conversion
X	Water/Cement Ratio	2	After conversion

**Figure A.4 - Relation between water/cement ratio and porosity of neat CAC paste**

### A.3.5 Resistance to chemical attack

The specific chemical composition of calcium aluminate cement, and the fact that calcium hydroxide is not released during hydration, allows properly compacted concretes made with this cement to resist many aggressive agents (see A.6.3). However if the porosity or permeability is high, as a result of conversion in concretes made with unsatisfactorily high W/C ratios, or poor workmanship during placing, they may become vulnerable to attack by alkalis or sulfates. In such cases releasable alkalis (K and Na) originating from either the aggregates, the mixing water or the environment (for example porous Portland cement concrete) can migrate into the CAC concrete. In the presence of atmospheric CO<sub>2</sub>, alkali carbonates may form, which may trigger the reaction known as alkaline hydrolysis with carbonation, and lead to the loss of integrity of the cement matrix.

Similarly, sulfates from the environment, e.g. from sulfated ground waters or gypsum plaster, may migrate into such concretes and mortars and this could lead to disruptive sulfate attack.

## A.4 Production of calcium aluminate cement concrete

### A.4.1 Choice of the aggregates

Use only aggregates meeting the standard requirements for aggregates in concrete (see EN 12620; see A.8 [6]) or, in mortar (EN 13139; see A.8 [7]). Avoid aggregates containing sands with releasable alkalis, particularly schists and rocks containing micas and feldspars.

In order to achieve the specified W/C ratio, it is essential to give proper care to the aggregates' water absorption and actual moisture content.

## A.4.2 Mixing the concrete

### A.4.2.1 General

The normal concreting techniques used for common cement concrete also apply to CAC concrete. The specific recommendations hereunder are of particular importance.

### A.4.2.2 Cleanliness of the equipment

Avoid any contact with residues of other types of cement or concrete, or with lime, so as to prevent an accelerated set. The equipment should be clean and free from any hardened concrete. The silo used to store the cement should be entirely emptied and cleaned before receiving the calcium aluminate cement.

### A.4.2.3 Cement content

The optimum cement content depends on the type of aggregates, their maximum size, the W/C ratio, the desired workability, and the specified strength requirements. In order to achieve satisfactory workability with a total W/C  $\leq 0,40$  without admixture, a minimum cement content of 400 kg/m<sup>3</sup> is recommended.

### A.4.2.4 Mixing water

It is essential that the mixing water is clean and conforms to EN 1008 (see A.8 [8]) with the additional requirement that the use of recycled water is not permitted. Sea water causes retardation of the setting time and should not be used in CAC concrete.

### A.4.2.5 Water/cement ratio

As illustrated in Figures A.3 and A.4, the strength and potential durability after conversion significantly decrease as W/C ratio increases. This fact should be properly considered when designing CAC concrete. For structural applications, a total W/C ratio not greater than 0,40 is recommended. For non-structural applications, appropriate converted strength and durability may be obtained with a total W/C ratio above 0,40.

## A.4.3 Placing and curing

As for every kind of concrete, it is important to ensure good compaction of the concrete made with calcium aluminate cement. Appropriate methods of compaction should be used (e.g. vibrating poker).

It is essential that the formwork is clean. Take care to avoid any loss of laitance.

It is necessary to prevent the drying out of the surface of the concrete by using a suitable curing method. Since calcium aluminate cement hydrates faster than Portland cement, the temperature of concrete during hardening is often higher. Therefore, due attention should be paid to the possibility of thermal cracking and greater caution is needed to achieve proper curing. Depending on the type of construction, appropriate curing methods should be applied in accordance with state-of-the-art rules.

## A.5 Admixtures

Concrete made of calcium aluminate cement, in construction works, is commonly placed without any admixture. Good workability is obtained by the use of high cement contents and compaction by the use of both high cement contents and low total W/C ratios.

It is possible to use admixtures with CAC concretes to modify fresh and/or hardened concrete properties. However it is important to know that admixtures according to EN 934-2 (A.8 [12]) recommended for common cements according to EN 197-1 can have a different effect with calcium

aluminate cement. Preliminary tests are necessary to demonstrate that the intended results are achieved with a specific admixture.

## **A.6 Use of calcium aluminate cement in particular conditions**

### **A.6.1 Concreting in cold weather**

The early and rapid exothermicity of calcium aluminate cement allows concreting to be carried out in cold weather.

Concrete may be placed at temperatures as low as  $-10\text{ }^{\circ}\text{C}$ , provided that the following precautions are taken:

- do not use frozen aggregates;
- use warm water for mixing;
- prevent the concrete from freezing until it begins to harden and the temperature begins to rise, i.e. approximately 4 h to 5 h after placing; this may be achieved by insulating with dry sacking, matting or sheeting etc.

### **A.6.2 Concreting in hot weather**

Concreting in hot weather can be carried out if the following precautions are taken:

- do not expose the constituents of the concrete to the sun;
- use chilled water for mixing;
- carefully cure the concrete as soon as possible by an appropriate method to avoid surface drying out under the combined effect of high air temperature and the heat released during hydration (A.4.3).

To maintain appropriate workability with time when concreting at high temperature, the use of an admixture having a retarding effect may be required. The choice of the admixture and its dosage should be determined by preliminary tests.

In the very special case, when all the materials would be at the same temperature, around  $28\text{ }^{\circ}\text{C}$  to  $30\text{ }^{\circ}\text{C}$ , a delay in hardening may occur because of the anomaly in the setting time/temperature curve.

### **A.6.3 Use in chemically aggressive environments**

Good quality CAC concrete, made in accordance with guidance given in this annex, may present a better resistance than Portland cement concrete against many aggressive substances. These include pure waters, water and ground containing sulfates, sea-water, diluted organic or mineral acids, as well as to solutions of organic products (sugars, oils, beers, wines and hydrocarbons) with a pH ranging from 4 to 11 (see also A.3.5).

The aggregate shall also be chosen according to its own resistance to the considered corrosive agent.

#### A.6.4 Maintenance and repair of works

CAC mortars and concretes may be used for the maintenance and repair of works made with common cement concrete.

Generally a bond is achieved between the two materials. In cases where soluble alkalis and CO<sub>2</sub> could migrate from wet, porous common cement concrete, towards the CAC mortar or concrete (see A.6.3), then an epoxy bonding agent is recommended.

#### A.6.5 Use in concrete with special properties

CAC concrete produced according to this annex has a good resistance to high temperature, thermal shocks and abrasion, provided aggregates are adequately selected.

### A.7 Rapid test to estimate the minimum long term strength of calcium aluminate cement concretes

#### A.7.1 Principle

Conversion is accelerated at high ambient temperatures, consequently the time to reach the minimum strength is reduced. At 38 °C this time period is 5 days and studies have established that the long term minimum strength will not fall below this value (see A.8 [5]). Results of this rapid test may therefore be used to estimate long term maximum design strengths of CAC concretes.

**NOTE** This period of 5 days has been established by numerous studies when concrete was immediately immersed after casting at 38 °C. However, if curing at 38 °C is delayed, the minimum strength occurs at a later age. For example, if curing is delayed for 24 hours after casting then the minimum strength occurs at 3 months (see A.8 [4] and Figure A.1). Furthermore, it has been shown that some aggregates and fillers, particularly those containing carbonates (e.g. limestone) may delay the conversion and the minimum strength may occur at later age. To establish minimum strength, further tests may be necessary at longer ages.

#### A.7.2 Equipment

- a) Standard laboratory or site concrete mixer;
- b) moulds of suitable form and dimension, preferably metallic (avoid the use of thermally insulating materials);
- c) means of placing and compacting the concrete;
- d) thermostatically controlled curing tank of suitable dimensions, capable of controlling the water temperature at  $(38 \pm 1) \text{ }^\circ\text{C}$ ;
- e) standard compression testing machine.

#### A.7.3 Test procedure

Immediately following the mixing of the concrete, cast test specimens in the required moulds ensuring proper compaction. Cover the top of the filled moulds with a glass or metal plate, which is in intimate contact with the surface of the concrete and the top edges of the mould.

Place the filled and covered mould into the tank (A.7.2 d)) ensuring that the mould is completely immersed.

After  $(24 \pm 1)$  h remove the mould from the tank and demould the concrete specimen. Immediately replace the concrete specimen in the tank to avoid cooling of the concrete.

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After a further 4 days (5 days after casting) remove the test specimens from the tank and measure the compressive strength according to the appropriate European Standard.

NOTE If necessary the test specimens may be transferred to a second tank of water at 20 °C for storage prior to testing but this period should not be more than 1 h.

Carry out tests in duplicate or triplicate and calculate the average strength.

### A.8 Bibliography

- [1] Robson T.D., High alumina cements and concretes, Contractors Records Ltd., London, 1962, fig. 23, p. 127.
- [2] George C.M., Industrial aluminous cements, Structure and performance of cements, P. Barnes Ed., London, Applied Science publishers, 1983, fig. 3, p. 423.
- [3] EN 1992-1-1, *Eurocode 2: Design of concrete structures — Part 1: General rules and rules for buildings*
- [4] Collins R.J., Gutt W., Research on long-term properties of high alumina cement concrete, Magazine of concrete research, Vol. 40, N° 145, December 1988, 195-208.
- [5] Teychenné D.C., Long term research into the characteristics of high alumina cement concrete, Magazine of concrete research, Vol. 27, N° 91, June 1975, 78-102.
- [6] EN 12620, *Aggregates for concrete*
- [7] EN 13139, *Aggregates for mortar*
- [8] EN 1008, *Mixing water for concrete — Specifications for sampling, testing and assessing the suitability of water, including wash water from recycling installations in the concrete industry, as mixing water for concrete*
- [9] George C.M., Manufacture and performance of aluminous cement: a new perspective, Calcium aluminate cements, R.J. Mangabhai Ed., E.&F.N. Spon, London (1990), 181-207.
- [10] Neville A.M., *Properties of concrete*, 4<sup>th</sup> and Final edition, Longman, 1995, p. 99.
- [11] Cottin B., Reif P., Paramètres physiques régissant les propriétés mécaniques des pâtes pures de liants alumineux, Revue des matériaux de construction, N° 661, octobre 1970, 293-306.
- [12] EN 934-2, *Admixtures for concrete, mortar and grout – Part 2: Concrete admixtures – Definitions, requirements, conformity, marking and labelling*

## Annex B (informative)

### Water-soluble hexavalent chromium

Some CEN member countries have regulations for the content of water-soluble hexavalent chromium.

Alteration of these national regulations is, for the time being, outside the competence of CEN/CENELEC members. In these countries these regulations are valid in addition to the relevant requirements of this European Standard until they have been removed.

For this European Standard the following national regulations have been applied according to EC-Directive 90/531 by Denmark, Finland, Germany, Iceland, Norway and Sweden.

- Denmark:       Arbejdstilsynets bekendtgørelse nr. 661 af 28. November 1983 om vandopløseligt chromat i cement.
- Finland:       Order of Council of State concerning limitations on cement and products containing cement, No 514, given on 16 June 2004.
- Germany:       Gefahrstoffverordnung (GefStoffV) together with TRGS 613 "Ersatzstoffe, Ersatzverfahren und Verwendungsbeschränkungen für chromathaltige Zemente und chromathaltige zementhaltige Zubereitungen, April 1993 (BArbBI Nr. 4.1993)".
- Iceland:       Reglur nr. 330/1989 um króm i sementi, Order No. 330 of 19 June 1989.
- Norway:       Directorate of Labour Inspection: Regulations relating to the Working Environment, laid down on 23 October 1987.
- Sweden:       Kemikalieinspektionens föreskrifter om kemiska produkter och biotekniska organismer, KIFS 1998:8,9 kapitlet §§ 10-13, Kemikalieinspektionens allmänna råd till föreskrifterna om krom i cement, 1989:1.

NOTE       Existing regulations are being replaced by transposition of the Directive 2003/53/EC.

## Annex ZA (informative)

### Clauses of this European Standard addressing the provisions of EU Construction Products Directive

#### ZA.1 Scope and relevant characteristics

This European Standard has been prepared under a Mandate M/114 “Cement, building limes and other hydraulic binders” given to CEN by the European Commission and the European Free Trade Association.

The clauses of this European Standard shown in this annex, meet the requirements of this mandate given under the EU Construction Products Directive (89/106/EEC).

Compliance with these clauses confers a presumption of fitness of the calcium aluminate cement covered by this annex for the intended use indicated herein; reference shall be made to the information accompanying the CE marking.

**WARNING — Other requirements and other EU Directives, not affecting the fitness for intended use(s), can be applicable to a construction product falling within the scope of this European Standard.**

NOTE 1 In addition to any specific clauses relating to dangerous substances contained in this European Standard, there may be other requirements applicable to the products falling within its scope (e.g. transposed European legislation and national laws, regulations and administrative provisions). In order to meet the provisions of the EU Construction Products Directive, these requirements need also to be complied with, when and where they apply.

NOTE 2 An informative database of European and national provisions on dangerous substances is available at the Construction web site on EUROPA, accessed through <http://europa.eu.int/comm/enterprise/construction/internal/dangsub/dangmain.htm>.

This annex establishes the conditions for the CE marking of the calcium aluminate cement intended for the uses indicated in Table ZA.1 and shows the relevant clauses applicable:

The scope of this annex is defined by Table ZA.1.

Table ZA.1 — Harmonised clauses

Construction Product: Intended use(s):		Calcium aluminate cement as covered under the scope of this European Standard. Preparation of concrete, mortar, grout and other mixes for construction and for the manufacture of construction products (see notes in this table)		CPD Article 3.2 level(s) and/or class(es)	Notes
Requirements/performance characteristics		Harmonised clauses in this European Standard			
Calcium aluminate cement constituents and composition	4	Constitution of the calcium aluminate cement, defined on the basis of constituent materials and composition.		None	Selection of the use of calcium aluminate cement by the Member States in technical regulations shall be possible.
	5			None	
Compressive strength (6 h and 24 h)	7.1 9	Compressive strength requirements expressed in terms of lower limits.		None	pass/fail
	7.2 9	Requirements expressed in terms of lower limit.		None	pass/fail
Alumina content	7.3 9	Requirements expressed in terms of lower and upper limits.		None	pass/fail
	7.3 9	Requirements expressed in terms of upper limit.		None	pass/fail
Chloride content	7.3 9	Requirements expressed in terms of upper limit.		None	pass/fail
	7.3 9	Requirements expressed in terms of upper limit.		None	pass/fail
Alkali content	7.3 9	Requirements expressed in terms of upper limit.		None	pass/fail
	7.3 9	Requirements expressed in terms of upper limit.		None	pass/fail
Durability	4 5			None	Durability relates to the concrete, mortar and other mixes for construction made from calcium aluminate cement according to the application rules valid in the place of use.

The requirement on a certain characteristic is not applicable in those Member States (MSs) where there are no regulatory requirements on that characteristic for the intended use of the product. In this case, manufacturers placing their products on the market of these MSs are not obliged to determine nor declare the performance of their products with regard to this characteristic and the option "No performance determined" (NPD) in the information accompanying the CE marking (see ZA.3) may be used. The NPD option may not be used, however, where the characteristic is subject to a threshold level.

## ZA.2 Procedure for the attestation of conformity of products

### ZA.2.1 System of attestation of conformity

The system of attestation of conformity for the calcium aluminate cement indicated in table ZA.1 is shown in Table ZA.2 for the indicated intended uses(s), in accordance with the Commission Decision of 14 July 1997 (97/555/EC) published in the Official Journal of the European Communities and given in Annex 3 of the Mandate for the product family "Cements".

**Table ZA.2 — System of attestation of conformity**

Product(s)	Intended use(s)	Level(s) or class(es)	Attestation of conformity system(s)
Calcium aluminate cement	Preparation of concrete, mortar, grout and other mixes for construction and for the manufacture of construction products	.....	1+
System 1+: See Annex III Section 2 point (i) of Directive 89/106/EEC, with audit-testing of samples taken at the factory			

The attestation of conformity to calcium aluminate cement in Table ZA.1 shall be based on the evaluation of conformity procedures indicated in Table ZA.3 resulting from application of the clauses of this European Standard indicated therein. Clause 6 of EN 197-2:2000 gives rules relating to actions in the event of non-conformity.

Clause 9 of EN 197-2:2000, giving rules relating to Dispatching Centres, is not part of the procedure of attestation of conformity for the affixing of the CE marking under the CPD. However, Member States, with their market surveillance obligations, must ensure that CE marking is correctly used (Article 15.1 of the CPD). Clause 9 of EN 197-2:2000 should be used for the corresponding national provisions concerning Dispatching Centres.

Table ZA.3 — Assignment of evaluation of conformity tasks

Tasks		Scope of the tasks	Clauses to apply
Tasks for the manufacturer	Factory production control	Parameters related to all relevant characteristics in Table ZA.1	Clause 9 and EN 197-2:2000, Clause 4
	Further testing of samples taken at the factory/depot <sup>c</sup>	All relevant characteristics in Table ZA.1 <sup>a</sup>	
Tasks for the notified body	Initial type testing	All relevant characteristics in Table ZA.1 <sup>a</sup>	Clauses 9 and EN 197-2:2000, Clauses 5 <sup>b</sup> and 7
	Initial inspection of factory and factory production control	Parameters related to all relevant characteristics in Table ZA.1 <sup>a</sup>	
	Continuous surveillance, assessment and approval of factory production control	Parameters related to all relevant characteristics in Table ZA.1 <sup>a</sup>	
	Audit-Testing of samples taken at the factory/depot	All relevant characteristics in Table ZA.1 <sup>a</sup>	
<p><sup>a</sup> Except durability.</p> <p><sup>b</sup> For calcium aluminate cement, the following numerical criteria shall apply in place of the values given in A.3.3 and A.3.4 of EN 197-2 (listed in Clause 5 of EN 197-2:2000):</p> <ul style="list-style-type: none"> <li>- <math> M_A - M_B  \leq 3,0 \text{ MPa}</math></li> <li>- <math>S_D \leq 5,0 \text{ MPa}</math></li> <li>- <math> M_B - M_C  \leq 5,0 \text{ MPa}</math>.</li> </ul> <p><sup>c</sup> Defined as autocontrol testing by the manufacturer in 9.1 and Table 3.</p>			

### ZA.2.2 EC certificate of conformity and EC declaration of conformity

When compliance with the conditions of this Annex is achieved, the certification body shall draw up a certificate of conformity (EC Certificate of conformity), which entitles the manufacturer to affix the CE marking. The certificate shall include:

- Name, address and identification number of the certification body;
- Name and address of the manufacturer, or his authorised representative established in the EEA, and place of production;
- Description of the product (type, identification, use, ...);
- Provisions to which the product conforms (e.g. Annex ZA of this EN);
- Particular conditions applicable to the use of the product (e. g. provisions for use under certain conditions, etc.);
- Number of the certificate;
- Conditions and period of validity of the certificate, where applicable;
- Name of, and position held by, the person empowered to sign the certificate.

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In addition, the manufacturer shall draw up a declaration of conformity (EC Declaration of conformity) including the following:

- name and address of the manufacturer, or his authorised representative established in the EEA;
- name and address of the certification body;
- description of the product (type, identification, use, ...), and a copy of the information accompanying the CE marking;
- provisions to which the product conforms (e.g. Annex ZA of this EN);
- particular conditions applicable to the use of the product (e.g. provisions for use under certain conditions, etc.);
- number of the accompanying EC Certificate of conformity;
- name of, and position held by, the person empowered to sign the declaration on behalf of the manufacturer or of his authorised representative.

The above mentioned declaration and certificate shall be presented in the official language or languages of the Member State in which the product is to be used.

### ZA.3 CE marking and labelling

The manufacturer or his authorised representative established within the EEA is responsible for the affixing of the CE marking. The CE marking symbol to affix shall be in accordance with Directive 93/68/EC and shall be shown on the bag of the calcium aluminate cement (or when not possible it may be on the accompanying label, the packaging or on the accompanying commercial documents e.g. a delivery note). The following information shall accompany the CE marking symbol:

- identification number of the certification body;
- name or identifying mark and registered address of the producer;
- last two digits of the year in which the marking is affixed;
- number of the EC Certificate of conformity or factory production control certificate;
- reference to this European Standard;
- description of the product: generic name, ... and intended use;
- information on those relevant essential characteristics listed in Table ZA.1 which are to be declared presented as:
  - declared values and, where relevant, level or class (including “pass” for pass/fail requirements, where necessary) to declare for each essential characteristic as indicated in “Notes” in Table ZA.1;
  - as an alternative, standard designation(s) alone or in combination with declared values as above, and;
  - “No performance determined” for characteristics where this is relevant.

The “No performance determined” (NPD) option may not be used where the characteristic is subject to a threshold level. Otherwise, the NPD option may be used when and where the characteristic, for a given intended use, is not subject to regulatory requirements in the Member State of destination.

Figure ZA.1 gives an example of the information to be given on the product, label, packaging and/or commercial documents.

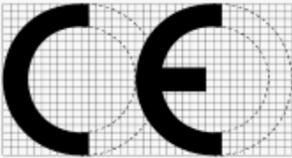
	CE conformity marking, consisting of the “CE”-symbol given in directive 93/68/EEC
0123	Identification number of the certification body
Any Company	Name or identifying mark of the producer
The registered address	Registered address of the producer
Any Factory <sup>2)</sup>	Name or identifying mark of the factory where the cement was produced <sup>1)</sup>
Year 04 (or position of date stamping)	The last two digits of the year in which the marking was affixed <sup>2)</sup>
0123-CPD-0456	Number of the EC certificate of conformity
EN 14647	Number of European Standard
CAC	Example of standard designation, indicating the cement product as specified in Clause 8 of this European Standard

Figure ZA.1 — Example of CE marking information

1) Considered necessary for the requirements of EN 197-2 but not compulsory.

2) The year of marking should relate to either the time of packing into bags or the time of dispatch from the factory or depot.

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For reasons of practicality, selections from the following alternative arrangements for bagged cement concerning the presentation of the accompanying information may be used:

- a) When the CE marking is given on the bag (this is the normal situation and is preferred) the elements shown on the Figure ZA.1 shall be given.
- b) Where the last two digits of the year in which the CE marking is affixed is pre-printed on the bag, the year so printed should relate to the date of affixing with an accuracy of within plus or minus three months.
- c) Where the last two digits of the year in which the marking is affixed is to be presented but not pre-printed on the bag it may be applied by means of date-stamping of the bag in any easily visible position. This position should be indicated in the information accompanying the CE marking.

In the case of bulk cement, the CE conformity marking, the identification number of the certification body and the accompanying information as listed before for bagged cement should be affixed in some suitable practical form on the accompanying commercial documents.

In addition to any specific information relating to dangerous substances shown above, the product should be accompanied, when and where required and in the appropriate form, by documentation listing any legislation on dangerous substances for which compliance is claimed, together with any information required by that legislation.

NOTE European legislation without national derogations need not be mentioned.

## Bibliography

- [13] EN 197-1, *Cement — Part 1: Composition, specifications and conformity criteria for common cements*