EUROPEAN ASSESSMENT DOCUMENT

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BLAST FURNACE CEMENT CEM III/A WITH ASSESSMENT OF SULFATE RESISTANCE (SR) AND OPTIONAL WITH LOW EFFECTIVE ALKALI CONTENT (LA) AND/OR LOW HEAT OF HYDRATION (LH)

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This European Assessment Document (EAD) has been developed taking into account up-to-date technical and scientific knowledge at the time of issue and is published in accordance with the relevant provisions of Regulation (EU) 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 "blast furnace cement CEM III/A with assessment of sulfate resistance (SR) and optional low heat of hydration (LH) and/or with a low effective alkali content (LA)" fulfils all requirements of a blast furnace cement CEM III/A according to EN 197-1 for a common cement and if applicable low heat of hydration.

Additionally to a common cement the "blast furnace cement CEM III/A" has a high resistance against sulfate attack on concrete (SR) and if submitted a low effective alkali content (LA).

To achieve a high sulfate resistance a minimum content of granulated blast furnace slag is specified (S_{min}), which is higher compared to the value given in EN 197-1 for a CEM III/A. A maximum content of minor additional constituents (MAC_{max}) ≤ 5 % by mass can be added. For the determination of the maximum clinker content the maximum content of minor additional constituents shall be taken into account ($K = 100-S_{min}-MAC_{max}$).

The assessment shall be carried out on a fixed cement composition (constituents (Portland cement clinker K, blast furnace slag S and minor additional constituents MAC) and composition), fineness of the cement and the manufacturing process. If one of the aforementioned factors is modified a new assessment is required.

The low effective alkali content (LA) of the "blast furnace cement CEM III/A" can be verified by the Na_2O-equivalent of the "blast furnace cement CEM III/A" and the granulated blast furnace content:

S_{min}: 45 to 49 % by mass and Na_2Oeq ≤ 0,95 % by mass

S_{min}: ≥ 50 % by mass and Na_2Oeq ≤ 1,10 % by mass

The product is not fully covered by the harmonised technical specification according to hEN 197-1, see Table 1.

Table 1: Comparison between cement composition, specifications and characteristics of EN 197-1

CEM III/A (SR)	Specifications of EN 197-1 (CEM III/A)
selected and defined granulated blast furnace slag with glass content ≥ 90 % by mass and ratio by mass $(CaO+MgO)/SiO_2$ ≥ 1,2	clause 5.2.2: glass content ≥ 66 % by mass and ratio by mass $(CaO+MgO)/SiO_2$ ≥ 1,0
content of blast furnace slag ≥ 45 % by mass	clause 6.1, table 1: Content of blast furnace slag ≥ 36 % by mass and ≤ 65 % by mass
Strength class ≥ 42,5 N	No requirement
optional low effective alkali content (LA)	Specifications of EN 197-1 (CEM III/A)
content of blast furnace slag 45 to 49 % by mass: Na_2Oeq ≤ 0,95 % by mass	clause 7.3: no requirement
content of blast furnace slag 50 % by mass: Na_2Oeq ≤ 1,10 % by mass	clause 7.3: no requirement

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.

Note: The "blast-furnace cement CEM III/A with high sulfate resistance (SR) and optional with a low effective alkali content (LA) and/or low heat of hydration (LH)" will be named as "Product".

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

1.2.1 Intended use(s)

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

Especially the "Product" is characterized by an evidently high resistance against sulfate attack on concrete and in case for the characteristic "LA" to prevent a damaging alkali silica reaction in the concrete.

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 "Product" for the intended use of 50 years when installed in the works provided that the "Product" is subject to appropriate installation (see 1.1). These provisions are based upon the current state of the art and the available knowledge and experience.

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.

1.3 Specific terms used in this EAD

The notations and symbols frequently used in this EAD are given below. Further particular notation and symbols are given in the text.

B = Basicity $(CaO + MgO)/(SiO_2)$

K = Portland cement clinker acc. to EN 197-1

GC = Glass content of the granulated blast furnace slag

MAC = Minor additional constituents acc. to EN 197-1

S = Blast furnace slag acc. to EN 197-1

LA = low effective alkali content

LH = low heat of hydratation

SR = high resistance against sulfate attack

[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.

2 ESSENTIAL CHARACTERISTICS AND RELEVANT ASSESSMENT METHODS AND CRITERIA

2.1 Essential characteristics of the product

Table 2 shows how the performance of "Product" is assessed in relation to the essential characteristics. The assessment shall be done on one batch.

Table 2 Essential characteristics of the product and methods and criteria for assessing the performance of the product in relation to those essential characteristics

No	Essential characteristic	Assessment method	Type of expression of product performance
Basic Works Requirement 1: Mechanical resistance and stability			
1	(CaO + MgO)/SiO_2-ratio of the granulated blast furnace slag	2.2.1	level (B [-])
2	Glass content of the granulated blast-furnace	2.2.2	level (GC [%])
3	Specific surface of the cement (Blaine)	2.2.3	level (ρ [cm^2/g])
4	Sulfate resistance	2.2.4	level [mm/m], description
Specification for common cement (CEM III/A)			
5	Early strength (2 d)	2.2.5	class [MPa] acc. to EN 197-1, clause 7.1, table 3
6	Standard strength (28 d)	2.2.6	class [MPa] acc. to EN 197-1, clause 7.1, table 3
7	Initial setting time	2.2.7	≥ 60 min for strength class 42,5 R ≥ 45 min for strength class 52,5 N or R acc. to EN 197-1, clause 7.2.1, table 3
8	Soundness	2.2.8	≤ 10 mm acc. to EN 197-1, clause 7.2.2, table 3
9	Loss on ignition	2.2.9	≤ 5,0 % by mass acc. to EN 197-1, clause 7.3, table 4
10	Insoluble residue	2.2.10	≤ 5,0 % by mass acc. to EN 197-1, clause 7.3, table 4
11	Sulfate content (as SO_3)	2.2.11	≤ 4,0 % by mass acc. to EN 197-1, clause 7.3, table 4
12	Chloride content	2.2.12	≤ 0,10 % by mass acc. to EN 197-1, clause 7.3, table 4
13	Composition of cement (main constituents) Clinker K Blast-furnace slag S MAC	2.2.13	K level [% by mass] S level [% by mass] MAC level [% by mass]
Specification for the characteristic low effective alkali content (LA) and low heat of hydration (LH) (optional)			
14	Alkali content of the cement (Na_2O_{eq})	2.2.14	level [% by mass]
15	Heat of hydration (LH)	2.2.15	≤ 270 J/g acc. to EN 197-1, clause 7.2.3

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

2.2.1 (CaO + MgO)/SiO_2-ratio of the granulated blast furnace slag

The chemical composition of the granulated blast furnace slag shall be determined in accordance with EN 196-2. The (CaO + MgO)/SiO_2-ratio (basicity) is calculated on the basis of the chemical composition.

The (CaO + MgO)/SiO_2-ratio of the granulated blast furnace slag shall be stated in the ETA.

2.2.2 Glass content of the granulated blast furnace slag

The glass content of the granulated blast furnace slag shall be determined by the test method given in Annex A.

The glass content of granulated blast furnace slag shall be given in the ETA.

2.2.3 Specific surface (Blaine) of the cement

The specific surface (Blaine) of the "Product" shall be determined by the air permeability method specified in EN 196-6.

The specific surface of the "Product" shall be given in the ETA.

2.2.4 Sulfate resistance (Flat prism method) - S_{FPM}

Sulfate resistance **S_{FPM}** of the product shall be tested according the test method described in Annex B on mortar specimens aged up to 26 weeks in a solution of Na_2SO_4, and in a solution of saturated Calcium hydroxide ($CaOH_2$). Differences of expansion and of Relative Dynamic Modulus of elasticity (RDM) of the product specimens aged in the two solutions at various ages shall be calculated.

That results for the "Product" and for the reference cements at 90 days and at 180 days, at a storage temperature of the specimens in the respective solutions (Na_2SO_4 and saturated $Ca(OH)_2$) at 20 and 5 °C, together with diagrams and a description of the failure or cracks of the specimens - if any - shall be given in the ETA.

2.2.5 Early strength

The early compressive strength of the "Product" shall be determined in accordance with EN 196-1 at 2 days.

The early compressive strength at 2 days shall be stated in the ETA.

2.2.6 Standard strength

The standard compressive strength of the "Product" shall be determined in accordance with EN 196-1 at 28 days.

The standard compressive strength at 28 days shall be stated in the ETA.

2.2.7 Initial setting time

The initial setting time of the "Product" shall be determined in accordance with EN 196-3.

The initial setting time shall be at least 45 minutes acc. to EN 197-1, table 3. The initial setting time shall be stated in the ETA.

2.2.8 Soundness

The soundness (expansion) of the "Product" shall be determined in accordance with EN 196-3.

The soundness (expansion) of the "Product" shall not be greater than 10 mm acc. to EN 197-1, table 3. The soundness (expansion) of the "Product" shall be stated in the ETA.

2.2.9 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 not exceed 5,0 % by mass acc. to EN 197-1, table 4. The loss on ignition of the product shall be stated in the ETA.

2.2.10 Insoluble residue

The insoluble residue of the "Product" shall be determined in accordance with EN 196-2.

The insoluble residue of the product shall not exceed 5,0 % by mass acc. to EN 197-1, table 4. The insoluble residue of the product shall be stated in the ETA.

2.2.11 Sulfate content (as SO_3)

The sulfate content (as SO_3), of the "Product" shall be determined in accordance with EN 196-2.

The sulfate content (as SO_3) of the product shall not exceed 4,0 % by mass acc. to EN 197-1, table 4. The sulfate content (as SO_3) of the product shall be stated in the ETA.

2.2.12 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 acc. to EN 197-1, table 4. For pre-stressing applications see note [f] in Table 4 of EN 197-1; in this case the lower value shall be stated in the ETA. The chloride content shall be stated in the ETA.

2.2.13 Composition of cement

The composition of the "Product" shall be determined in accordance with CEN/TR 196-4.

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

Portland cement clinker (K)	35 to 50 % by mass
Granulated blast furnace slag (S)	45 to 65 % by mass
Minor additional constituents (MAC)	0 to 5 % by mass

The composition of the "Product" and the range shall be stated in the ETA. The range is given by the manufacturer.

2.2.14 Alkali content of the cement (Na_2O_{eq}) (optional)

The chemical composition of the "Product" shall be determined in accordance with EN 196-2. The Na_2O_{eq} is calculated by the formula:

$Na_2O_{eq} = Na_2O + 0{,}658\ K_2O$

The Na_2Oeq content is given in the ETA.

2.2.15 Heat of hydration (LH) (optional)

The heat of hydration of "Product" shall be determined in accordance with EN 196-8 at 7 days or in accordance with EN 196-9 at 41 h.

The heat of hydration of "Product" shall not exceed the value of 300 J/g (single value) according to EN 197-1, table 10, determined in accordance with either EN 196-8 at 7 days or in accordance with EN 196-9 at 41 h.

The head of hydration shall be stated in the ETA. If the "product" fulfils the above mentioned requirement it can be identified by the notation "LH".

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: Commission Decision 97/555/EC.

The system is: 1+

3.2 Tasks of the manufacturer

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

Table 3 Control plan for the manufacturer; cornerstones

No	Subject/type of control	Test or control method	Criteria, if any	Minimum number of samples	Minimum frequency of control
Factory production control (FPC) [including testing of samples taken at the factory in accordance with a prescribed test plan]					
1	(CaO + MgO)/SiO_2-ratio of the granulated blast furnace slag	2.2.1	level	1	1/week[a] 1/month[b]
2	Glass content of the granulated blast furnace	2.2.2	level	1	
3	Specific surface of the cement (Blaine)	2.2.3	level	1	1/week[a] 2/month[b]
4	Early compressive strength (2 d)	2.2.5	≥ 8,0 MPa (42,5 N) [1)] ≥ 18,0 MPa (42,5 R, 52,5 N and 52,5 R) [1)] lower limit value	1	4/week[a] 2/week[b]
5	Standard compressive strength (28 d)	2.2.6	≥ 40,0 MPa (42,5 N or 42,5 R) [1)] ≥ 50,0 MPa (52,5 N or 52,5 R) [1)] lower limit value	1	
6	Initial setting time	2.2.7	≥ 50 min (42,5 R) [1)] ≥ 40 min (52,5 N or R) [1)] lower limit value	1	
7	Soundness	2.2.8	≤ 10 mm [1)] upper limit value	1	4/week[a] 1/week[b]
8	Loss on ignition	2.2.9	≤ 5,0 % by mass	1	1/week[a] 2/month[b,c]
9	Insoluble residue	2.2.10	≤ 5,0 % by mass [1)]	1	
10	Sulfate content (as SO_3)	2.2.11	≤ 4,5 % by mass [1)] upper limit value	1	4/week[a] 2/week[b]
11	Chloride content	2.2.12	≤ 0,10 % by mass [1)] upper limit value	1	1/week[a] 2/month[b,c]
12	Composition of cement Clinker K Blast-furnace slag S MAC	2.2.13	K (x ± y % abs.) S (x ± y % abs.) MAC (x ± y % abs.) (x ± y % abs.) Level [% by mass (x ± y % abs.)]	1	1/week[a] 1/month[b]
Specification for the characteristic low effective alkali content (LA) and low heat of hydration (LH) (optional)					
13	Alkali content of the cement (Na_2O_{eq})	2.2.14	level	1	4/week[a] 2/week[b]

No	Subject/type of control	Test or control method	Criteria, if any	Minimum number of samples	Minimum frequency of control
14	Heat of hydration (LH)	2.2.15	≤ 300 J/g [1)] upper limit value ≤ 270 J/g [1)] characteristic value	1	1/week[a] 1/month[b]

[a] Initial period acc. to EN 197-1, table 6

[b] Routine situation acc. to EN 197-1, table 6

[c] 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 acc.to EN 197-1.

[1)] Limit values for single results according to EN 197-1, table 1

x stated value from the assessment testing

y spread given by the manufacturer

3.3 Tasks of the notified body

The cornerstones of the actions to be undertaken by the notified body of the product in the procedure of assessment and verification of constancy of performance are laid down in Table 4.

Table 4 Control plan for the notified body; cornerstones

No	Subject/type of control *(product, raw/constituent material, component - indicating characteristic concerned)*	Test or control method	Criteria, if any	Minimum number of samples	Minimum frequency of control
Initial inspection of the manufacturing plant and of factory production control					
	acc. to EN 197-2				
Continuous surveillance, assessment and evaluation of factory production control					
	acc. to EN 197-2				
Audit-testing of samples taken by the notified product certification body at the manufacturing plant or at the manufacturer's storage facilities					
	see Table 3 (no. 1 to no. 14)			1	6/year acc. to EN 197-1

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.

CEN/TR 196-4	Methods of testing cement - Part 4: Quantitative determination of constituents
EN 196-1	Method of testing cement – Part 1: Determination of strength
EN 196-2	Method of testing cement – Part 2: Chemical analysis of cement
EN 196-3	Method of testing cement – Part 3: Determination of setting times and soundness
EN 196-6	Methods of testing cement - Part 6: Determination of fineness
EN 196-8	Methods of testing cement - Part 8: Heat of hydration — Solution method
EN 196-9	Methods of testing cement - Part 9: Heat of hydration — Semi-adiabatic method
EN 197-1	Cement – Part 1: Composition, specifications and conformity criteria for common cements
EN 197-2	Cement – Part 2: Conformity evaluation

Annex A - Determination of the glass content of granulated blast furnace slag

A.1 General

Granulated blast furnace slag is produced in blast furnace plants as moist granules with a grain size of 0 to 5 mm. The following test instructions have proved successfully for determination of the glass content by microscope.

A.2 Test equipment

The below-mentioned test equipment is necessary to carry out the test:

- porcelain mortar with pestle
- drying cabinet for 105 °C, or vacuum cabinet
- air-jet screening machine
- air-jet screen with 0,04 mm mesh
- hand sieve with 0,06 mm mesh
- hot plate with temperature control
- Canada balsam
- microscope slide and cover glass
- polarizing microscope for transmitted light (up to 250 x magnification), if possible with whole-wave plate (e.g. quartz red I) as auxiliary objective lens.

A.3 Sample preparation

The sample of granulated blast furnace slag of approximately 500 g is dried in a drying cabinet at 105 °C or in a vacuum cabinet at room temperature.

The dried sample is then split to give a sub-sample of approximately 25 g. This sub-sample is completely comminuted by careful grinding until no residue remains on the 0-0,06 mm mesh hand sieve. Thereafter the fraction smaller than 0,04 mm is screened off with air-jet screen. In order to obtain a homogeneous dispersed preparation which is free from fines and oversize material the 0,04 mm to 0,06 mm particle size fraction is again screened on the 0,06 mm hand sieve mesh and air-jet screen with 0,04 mm mesh. The particle size fraction 0,06 to 0,04 mm is sufficiently fine for investigation under a microscope.

A microscope slide is placed on a hot plate heated to approximately 130 °C and enough Canada balsam is melted on it to cover about the third of the slide with melted Canada balsam. The heating is continued until no more little bubbles can be seen. A small quantity of the screened grains of granulated blast furnace slag is scattered on the softened Canada balsam with spatula and the dispersed granulated preparation is covered with a cover glass. A thin uniform layer of Canada balsam and screened granulated blast furnace slag is generated by light pressure and movement of the cover glass. After cooling, the grains of granulated blast furnace slag should be distributed evenly in the Canada balsam without forming lumps. Excess Canada balsam is removed with xylene. The finished dispersed preparation is investigated with a microscope using polarized transmitted light at 200 to 250 x magnification.

A.4 Test execution

With crossed polarizers the glassy particles remain dark. Cubically crystallized components also remain dark, but such components are extremely rare in granulated blast furnace slag and can therefore be ignored when determining the glass content. The other crystalline components appear light. When the microscope stage is rotated through 90° these crystalline components appear alternately light and dark.

The use of whole-wave plate (e.g. quartz red I) with crossed polarizers makes it easier to differentiate between crystalline and non-crystalline components. In this case the glassy components have the same uniform colour as the background all the time and can only be detected by their contours. Crystalline nonglossy components stand out by having a different colour from the background.

A.5 Determination of the glass content

To determine the glass content it is necessary to count at least 1000 grains and classify them into the following groups:

A: purely glassy grains

B: glassy grains (approx. 90 % glass) with small crystalline content

C: glassy grains (approx. 40 % glass) with increased crystalline content

D: grains with no glassy components (approx. 0 % glass)

E: foreign components, e.g. opaque particles

The glass content G in percent is calculated by following formula:

$$G[\%] = \frac{(A + 0{,}9 \cdot B + 0{,}4 \cdot C)}{(A + B + C + D)}$$

The fraction of foreign constituents E is not taken into account when calculating the glass content.

ANNEX B - TESTING THE SULFATE RESISTANCE OF BLAST-FURNACE SLAG CEMENT CEM III/A – FLAT PRISM METHOD SFPM

B.1 References

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

B.2 General description of the test method

The sulfate resistance of the hydraulic binder according to the flat prism method ($\mathbf{S_{FPM}}$) shall be tested on specimens made of mortar according to EN 196-1; some specimens will be fitted with pins for measurement of the length, the others will be used for the control of the Relative Dynamic Modulus of elasticity (RDM).

The storage of the specimens after removal of the formwork shall be made up to 2 weeks of age in a saturated solution of calcium hydroxide; Then, half of the prisms will be transferred into two containers with a 4,4 % sodium sulfate (Na_2SO_4) solution, one of them maintained at the temperature of 5 °C and the other at 20 °C. The other prisms will be kept still in saturated calcium hydroxide solution ($Ca(OH)_2$), half of these at 5 °C and half at 20 °C. All of them will be weighed before the measurement to check for any weight changes; all measures will be carried out at every maturities up to 180 days.

All the values shall be reported in the ETA together with any annotations on the presence of cracks or swelling or otherwise.

B.3 Assessment cements

The sulfate resistance shall be tested on specimens made of mortar according to EN 196-1 for the "Product" to be examined and two reference cements (standard CEM I 42,5 R – SR 3 and CEM III/B 42,5 N-LH/SR according to EN 197-1) according to the flat prism method.

B.4 Preparation of test specimens

24 flat prisms from each mortar with the dimensions 10 mm x 40 mm x 160 mm (12 with and 12 without measuring pin) shall be made in accordance with and/or following EN 196-1 and be compacted on the vibrating table.

B.5 Storage of test specimens

The 24 flat prisms shall first of all be stored for 2 days in the mould at (20 ± 2) °C and > 95 % RH (climate 20/95).

After demoulding the 24 flat prisms shall be pre-stored until the age of 14 days, on edge, standing on gratings in saturated $Ca(OH)_2$ solution at (20 ± 2) °C.

At the age of 14 days, a series of 3 flat prisms with measuring pin and 3 flat prisms without measuring pin will be stored on edge, standing on gratings (sulfate storage) in a 4,4 % Na_2SO_4 solution at 5 °C and 20 °C. One series each of 3 flat prisms with measuring pin and 3 flat prisms without measuring pin will be stored on edge, standing on gratings (reference storage 5 °C) in a saturated $Ca(OH)_2$ solution at 5 °C. The other two series of 3 flat prisms each remain stored in saturated $Ca(OH)_2$ at 20 ± 2 °C (reference storage (20 ± 2) °C).

In all storages the ratio of volumes of solution/solid matter must be 3:1 to 5:1. The Na_2SO_4 solution is to be replaced every 14 days with a new Na_2SO_4 solution, temperature-controlled at 5 °C respectively 20 °C. The saturated $Ca(OH)_2$ solution is to be checked every 14 days. If necessary it has to be concentrated.

B.6 Test

The length of the flat prisms (specimens with pins) and the dynamic modulus of elasticity (RDM) of the flat prisms (specimens without pin) will be measured after a period of storage of 0, 14, 28, 56, 90, and 180 days. In addition the change in mass of the flat prisms is to be determined.

Photos of the specimens will be taken after every testing to illustrate the formation of the cracks.

B.7 Analysis

The elongation of the flat prisms is to be determined as mean value of the measured values from 3 specimens and the difference in elongation between the sulfate storage and the reference storage is to be assessed.

The dynamic modulus of elasticity is to be determined as mean value from the measured values from 3 specimens.

The elongation difference and the dynamic modulus of elasticity and the photos are to be stated in the test report for all test steps.

The expansion (in percent) of every prism at time (t) shall be determined by the equation:

$$\Delta L\ (\%) = (L_t - L_0) \times 100/160$$

where:

ΔL = length variation between time (t) and time (0), as a percentage of the length of the prism (160 mm) excluding pins.

L_0 = prism length at time (0)

L_t = prism length at time (t)

The difference between the average of ΔL (%) of the group of prisms cured in sulfate solution and the corresponding cured in calcium hydroxide solution shows the length variation Δ_{SS} (%) due to the sulfate storage at time (t); the value of Δ_{SS} may be included in a diagram with the aim of showing more clearly the trend of the samples length in time.