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EAD 150080-00-0301

August 2023

European Assessment Document for

Blended cements with high filler content, ground granulated blast-furnace slag or pozzolanic material or both, and clinker

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

Contents

1 SCOPE OF THE EAD

1.1 Description of the construction product

Blended cements with high filler content, ground granulated blast-furnace slag or pozzolanic material or both, and clinker are referred to in this document as "blended cement". It is manufactured according to a specific procedure, and the composition shall comply with ranges in Table 1.1.1.

Table 1.1.1 Composition range of the blended cement

Component	Range in %mass
GGBS	0-69
Pozzolanic material (natural (P) and natural calcined pozzolana (Q)	0-69
Portland cement clinker	10-34
Limestone (L, LL) or dolomitic limestone	21-70
Calcium sulphate	0-5
Minor additional constituents	less than or equal to 5
Additives	less than 5

The components of the blended cement are:

- Ground granulated blast-furnace slag (GGBS)

  Fine powder made by grinding granulated blast-furnace slag (GBS). GBS is a vitrified material made by rapid cooling of a slag melt of suitable composition, obtained by smelting iron ore in a blast furnace, consisting of at least two thirds by mass of glassy slag and possessing hydraulic properties when suitably activated (in accordance with EN 15167-1[1]).

  The GGBS, for which this EAD applies, complies with EN 15167-1 with the following deviations:

  - Constituents (Clause 4) except for mass ratio of $(CaO + MgO)/SiO_2$ which shall be greater or equal to 1.2
  - The activity index (Clause 5.3.2.3) shall not be less than 65 % after 7 days of curing, and not be less than 85 % after 28 days of curing.
  - The specific surface (Clause 5.3.1) shall not be less than 420 m^2/kg (determined in accordance with the air permeability method (Blaine) specified in EN 196-6).
- Pozzolanic materials

  Pozzolanic materials are natural (P) and natural calcined pozzolana (Q) in accordance with EN 197-1, Clause 5.2.3.
- Limestone (L, LL) or dolomitic limestone

  Limestone (L, LL) or dolomitic limestone in accordance with EN 197-5, Clause 4.
- Portland cement clinker

  Portland cement clinker in accordance with EN 197-1, Clause 5.2.1.
- Calcium sulphate

  Calcium sulphate in accordance with EN 197-1, Clause 5.4.
- Minor additional constituents

  Specially selected inorganic material used in a proportion not exceeding a total of 5 % by mass related to the sum of all main constituents.

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

- Additives

  Additives are constituents not listed in the previous paragraphs that are added to improve the production or properties of the blended cement.

The blended cement is not covered by the following harmonised technical specification: EN 197-1 (Table 1). EN 197-1 does not take into account blended cements for the considered composition. EN 197-5 allows these components (GGBS, clinker, filler), but not in the proportions proposed in this blended cement.

Therefore, some of the assessment methods prescribed in EN 197-1 in order to assess the mechanical performances of the blended cement are modified.

- Early strength (Clause 7.1.2): modification of the composition of the mortar; result as level instead of class;
- Standard strength (Clause 7.1.1): modification of the composition of the mortar; result as a level instead of class;
- Initial setting time (Clause 7.2.1): direct reference to assessment method because the reference to Table 3 is not meaningful (no class);
- Heat of hydration (Clause 7.2.3): modification of the composition of mortar;
- Sulphate content (see Clause 2.2.7): direct specification of a clause of EN 196-2 to avoid the reference to Table 4 of EN 197-1, which is not relevant.

Additionally, several assessment methods are added to the BWR 1 section in order to better characterize the blended cement:

- Fineness (see Clause 2.2.1): to indicate its reactivity;
- Long-term strength (see Clause 2.2.5: to indicate the kinetic of its hydration;
- Final setting time (see Table 2.1.1): this information is required for some usages;
- Sodium oxide equivalent (Na_2O_{eq}) (see Clause 2.2.2): to guide the choice of aggregates.

Additionally, two assessments methods are added in BWR 3 section due to legal requirements:

- Content, emission and/or release of dangerous substances (see Clause 2.2.8);
- Water-soluble hexavalent chromium content (see Clause 2.2.9).

Finally, concerning the durability as expressed in the table ZA.1, several mixes are chosen to be in line with the intended uses and several essential characteristics are defined:

- Compressive strength of the blended cement mixed with aggregates (after 1, 2, 7, 28 and 90 days) (see Clause 2.2.10): to indicate the kinetic of the compressive strength;
- Shrinkage of the blended cement mixed with sand (see Clause 2.2.11): to indicate its level of shrinkage when mixed with sand;
- Shrinkage of the blended cement mixed with aggregates (see Clause 2.2.12): to indicate its level of shrinkage when mixed with aggregates;
- Creep (total, basic and drying) in compression of the blended cement mixed with aggregates (see Clause 2.2.13): to indicate levels of creep under compression when mixed with aggregates;
- Resistance against sulphates at 20 °C of the blended cement (Clause 7.4.2 of the standard modified, see Clause 2.2.14): to indicate its level of resistance against sulphate at standard temperature;
- Resistance against sulphates at 5 °C of the blended cement (see Clause 2.2.15): to indicate its level of resistance against sulphate at standard low temperature;
- Resistance to chloride penetration, unidirectional diffusion, of the blended cement mixed with aggregates (see Clause 2.2.16): to indicate its level of resistance against chloride;
- Chloride migration in the blended cement mixed with aggregate (see Clause 2.2.17): to indicate its level of resistance against chloride (accelerated method);
- Basicity of the pore water solution in the blended cement mixed with aggregates (see Clause 2.2.18): to indicate its corrosiveness after hydration;
- Carbonation rate of the blended cement mixed with aggregates (see Clause 2.2.19): to indicate its rate of carbonation;
- Resistance to carbonation of the blended cement mixed with aggregates in accelerated test (see Clause 2.2.20): to indicate its carbonation kinetics in accelerated conditions;
- Resistance to alkali-silica reaction of the blended cement mixed with aggregates (see Clause 2.2.21): to indicate its resistance to alkali-silica reaction when mixed with reactive aggregates.

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

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

Relevant manufacturer's stipulations, e.g., with regard to the intended end use conditions, having influence on the performance of the product covered by this European Assessment Document shall be considered for the determination of the performance and detailed in the ETA as long as the details of the assessment methods as laid down in this EAD are respected.

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

1.2.1 Intended use(s)

The blended cement is intended to be used for preparation of concrete, mortar and other mixes for construction works and for the manufacturing of prefabricated construction products.

The blended cement shall be used with a low water-cement ratio (below 0.4).

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 blended cement, for the intended use of 100 years when installed in the works (provided that the blended cement is subject to appropriate use (see Clause 1.2.1)). 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[2].

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 Notations and symbols frequently used in this EAD

1.3.1 Starting with a Roman letter

C	Cement
Dk	Arithmetic average of carbonation depth
D_{max}	Coarsest fraction of aggregate
D_{nss}	Chloride diffusion coefficient
$E_{d,NS,(ti,T)}$	Dynamic modulus of elasticity of specimen in the sulphate solution
$E_{d,CH,(ti,T)}$	Dynamic modulus of elasticity of specimen in saturated $Ca(OH)_2$ solution
$E_{d,0}$	Initial dynamic modulus of elasticity of specimen
f_c	Compressive strength
$F_{L,CH(ti,T)}$	Longitudinal resonance frequency of specimen in saturated $Ca(OH)_2$ solution
$F_{L,NS(ti,T)}$	Longitudinal resonance frequency of specimen in sulphate solution
GBS	Granulated Blast-furnace slag
GGBS	Ground Granulated Blast-furnace slag
K_{AC}	Carbonation rate in accelerated conditions
k_c	Carbonation rate in natural conditions

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

l	Length of the core
l_0	Length of the core before the first cycle
$l_{CH,(ti,T)}$	Specimen length at storage time (t_i) in $Ca(OH)_2$ solution
l_i	Initial length of prism i
l_n	Measured length after n weeks
$l_{NS,(ti,T)}$	Specimen length at storage time (t_i) in sulphate solution
m_{sn}	Mass after storage in the sulphate solution after n weeks
m_{sv}	Mass after drying after the previous measure
m_{Tn}	Mass after drying after n cycles
$m\Delta E_{age}$	Mean length change
$m\Delta W_{age}$	Mean weight change
Na_2O_{eq}	Sodium oxide equivalent
RDM	Relative Dynamic Modulus of elasticity
RH	Relative humidity
$SO_3\%$	Sulphate content in %
T	Temperature
t_0	Test beginning
t_i	Storage time
V_0	Initial volume
w_0	Initial mass of the specimen
$w_{0,i}$	Mass of the specimen i after demoulding
$w_{CH,(ti,T)}$	Mass of the specimen in saturated $Ca(OH)_2$ solution
W_{Eff}/B	Efficient water to blended cement ratio
W_{Eff}/C	Efficient water to cement ratio
$w_{NS,(ti,T)}$	Mass of the specimen in sulphate solution
$W_{t,i}$	Mass of the specimen i at t time

1.3.2 Starting with a Greek letter

ΔE_{age}	Individual length change
$\Delta l_{CH,(ti,T)}$	Mean length difference of the flat prism in a saturated $Ca(OH)_2$ solution
Δln	Length change after n weeks
$\Delta l_{NS,(ti,T)}$	Mean length difference of the flat prism in the sulphate solution
Δl_s	Sulphatic elongation after permanent storage in sulphate solution
$\Delta l_{ti,T}$	Expansion of length
Δm	Change in mass
Δm_{sn}	Mass change after permanent storage in the sulphate solution
ΔW_{age}	Individual weight change

2 ESSENTIAL CHARACTERISTICS AND RELEVANT ASSESSMENT METHODS AND CRITERIA

2.1 Essential characteristics of the product

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

Table 2.1.1 Essential characteristics of the product, and methods and criteria for assessing the performance of the product in relation to those essential characteristics

No	Essential characteristic[3]	Assessment method	Type of expression of product performance
Basic Works Requirement 1: Mechanical resistance and stability			
1	Fineness	2.2.1	Level
2	Insoluble residue	EN 196-2, Clause 4.4.3	Level
3	Loss on ignition	EN 196-2, Clause 4.4.1	Level
4	C_3A content in clinker	EN 197-1, Clause 5.2.1	Level
5	Sodium oxide equivalent (Na_2O_{eq}) of the blended cementSodium oxide equivalent (Na_2O_{eq}) of the blended cement	2.2.2	Level
6	Early strength	2.2.3	Level
7	Standard strength	2.2.4	Level
8	Long-term strength	2.2.5	Level
9	Initial setting time	EN 196-3, Clause 6.2	Level
10	Final setting time	EN 196-3, Clause 6.3	Level
11	Soundness (expansion)	EN 197-1 Clause 7.2.2	Level
12	Heat of hydration	2.2.6	Level
13	Sulphate content	2.2.7	Level
14	Chloride content	EN 197-1, Clause 7.3	Level
15	Pozzolanicity	EN 197-1 Clause 7.3	Level
Basic Works Requirement 3: Hygiene, health and the environment			
16	Content, emission and/or release of dangerous substances	2.2.8	Level
17	Water-soluble hexavalent chromium	2.2.9	Level
Aspects of durability			
18	Compressive strength of the blended cement mixed with aggregates (at 1, 2, 7, 28, and 90 days)	2.2.10	Level
19	Shrinkage of the blended cement mixed with sand	2.2.11	Level

3 In accordance with EN 197-1, Table ZA.1, insoluble residue and loss on ignition are required only for CEM I and CEM III, pozzolanicity is required only for CEM IV, and C_3A is required only for sulphate resistant common cements.

No	Essential characteristic[3]	Assessment method	Type of expression of product performance
20	Shrinkage of the blended cement mixed with aggregates	2.2.12	Level
21	Creep (total, autogenous and drying) of the blended cement mixed with aggregates in compression	2.2.13	Level
22	Resistance against sulphate at 20 °C of the blended cement	2.2.14	Level and description
23	Resistance against sulphate at 5 °C of the blended cement	2.2.15	Level and description
24	Resistance to chloride penetration, unidirectional diffusion, of the blended cement mixed with aggregates	2.2.16	Level
25	Chloride migration in the blended cement mixed with aggregates	2.2.17	Level
26	Basicity of the pore water solution in the blended cement mixed with aggregates	2.2.18	Level
27	Carbonation rate of the blended cement mixed with aggregates	2.2.19	Level
28	Resistance to carbonation of the blended cement mixed with aggregates in accelerated test	2.2.20	Level
29	Resistance to alkali-silica reaction of the blended cement mixed with reactive aggregates	2.2.21	Level

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

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

2.2.1 Fineness

Purpose of the assessment

Determination of the fineness of the mixed component.

Assessment method

Fineness shall be determined in accordance with EN 196-6, Clause 4, with the Blaine method.

Expression of result(s)

The fineness of the blended cement as specific surface area (cm^2/g) and the formula shall be stated in the ETA.

2.2.2 Sodium oxide equivalent (Na_2O_{eq}) of the blended cement

Purpose of the assessment

Determination of total alkali content of the blended cement.

Assessment method

Alkali content of the blended cement shall be determined in accordance with EN 196-2, Clauses 4.5.19 (reference method) or 4.5.20 (alternative method). For both methods, the test conditions shall be in accordance with EN 196-2, Clause 3. The Na_2O_{eq} shall be calculated by the formula:

$$Na_2O_{eq} = Na_2O + 0.658\ K_2O$$

Expression of result(s)

The Na_2O_{eq} (%mass) and the test method shall be stated in the ETA.

2.2.3 Early strength

Purpose of the assessment

Determination of the early strength of blended cement.

Assessment method

Determined in accordance with EN 196-1, Clause 9.2, with the following modifications regarding the mix preparation (Clause 6.1 of EN 196-1):

- Mix composition (in accordance with EN 14647, Clause 7.1): 1350 g of sand, 500 g of blended cement, 200 g of water, and superplasticizer (if necessary, flow ≥ 120 mm measured in accordance with EN 1015-3).
- After demoulding, the specimens shall be stored in water at (20 ± 2) °C.

The tolerances of EN 196-1, Clauses 6.1 and 8.2 shall apply.

Expression of result(s)

The early strength (MPa) and the duration for the test (2 d or 7 d) shall be stated in the ETA.

2.2.4 Standard strength

Purpose of the assessment

Determination of the strength of the blended cement at 28 days.

Assessment method

Standard strength at 28 days shall be determined in accordance with EN 196-1, Clause 9.2, with the following modifications regarding the mix preparation (Clause 6.1 of EN 196-1):

- Mix composition (in accordance with EN 14647, Clause 7.1): 1350 g of sand, 500 g of blended cement, 200 g of water, and superplasticizer (if necessary, flow ≥ 120 mm measured in accordance with EN 1015-3)).
- After demoulding, the specimens shall be stored in water at (20 ± 2) °C.

The tolerances of EN 196-1, Clauses 6.1 and 8.2 shall apply.

Expression of result(s)

The standard strength (MPa) at 28 days shall be stated in the ETA.

2.2.5 Long-term strength

Purpose of the assessment

Determination of the strength of the blended cement at 90 days.

Assessment method

Long-term strength shall be determined in accordance with EN 196-1, Clause 9.2, with the following modifications regarding the mix preparation (Clause 6.1 of EN 196-1):

- Mix composition (in accordance with EN 14647, Clause 7.1): 1350 g of sand, 500 g of blended cement, 200 g of water, and superplasticizer (if necessary, flow ≥ 120 mm measured in accordance with EN 1015-3)).
- After demoulding, the specimens shall be stored in water at (20 ± 2) °C.

The tolerances of EN 196-1, Clauses 6.1 and 8.2 shall apply.

Expression of result(s)

The long-term strength (MPa) shall be stated in the ETA.

2.2.6 Heat of hydration

Purpose of the assessment

Determination of the thermal flux and cumulative heat over time of the blended cement.

Assessment method

Heat of hydration shall be determined on a mix in accordance with EN 196-9 at 41 hours, with the following modifications regarding the mix composition (Clause 6 of EN 196-1):

- 1080 g of sand, 400 g of blended cement, 160 g of distilled or deionised water.

The tolerances of EN 196-9, Clause 7.2 shall apply.

Expression of result(s)

The heat of hydration (J/g) shall be stated in the ETA.

2.2.7 Sulphate content

Purpose of the assessment

Determination of the sulphate content of the blended cement.

Assessment method

The sulphate content (expressed as SO_3) of the blended cement, shall be determined in accordance with EN 196-2, Clause 4.4.2. EN 196-2, Clause 3 shall be fulfilled.

Expression of result(s)

The sulphate content (% in mass) and the test method shall be stated in the ETA. It shall be less than or equal to 3.5 % in mass in accordance with EN 197-1, Table 4.

2.2.8 Content, emission and/or release of dangerous substances

Purpose of the assessment

Determination of content, emission and/or release of dangerous substances contained in the cement.

Assessment method

The performance of the product related to the emissions and/or release and, where appropriate, the content of dangerous substances shall be assessed on the basis of the information provided by the manufacturer[4] after identifying the release scenarios taking into account the intended use of the product and the Member States where the manufacturer intends his product to be made available on the market.

The identified intended release scenario[5] for this product and intended use with respect to dangerous substances are:

- S/W1: Product with direct contact to soil, ground- and surface water
- S/W2: Product with indirect contact to soil, ground- and surface water

For the intended use covered by the release scenario S/W1 or S/W2, the performance of the product concerning leachable substances shall be assessed. A leaching test with subsequent eluate analysis shall be done, each in triplicate.

Elution test specimens shall be made of Mix A (see

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

The manufacturer is **not** obliged to:

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

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

5 Scenario S/W1 is applicable for products which are in contact with soil or water in a way that dangerous substances could be released directly out of the product.

Scenario S/W2 is applicable for products which can be leached by rain (e.g., external claddings) and could release dangerous substances which can have an impact on soil and water.

Table 2.2.10.1).

Cubes with edge of 100 mm of mix shall be made in accordance with EN 12390-2 (form oil shall not be used).

The specimens shall be stored for (24 ± 2) hours in the mould, protected from drying at (20 ± 2) °C and at a relative air humidity greater than 95 %.

After demoulding, the test specimens shall be airtight packaged (e.g., immediately double-wrapped in plastic foil (at least 0.3 mm thick), and all free edges of the plastic foil stuck down with adhesive tape) and stored at a temperature of (20 ± 2) °C. The test specimens shall be stored for 56 days.

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

- antimony, arsenic, barium, lead, cadmium, chromium (total), cobalt, copper, molybdenum, nickel, mercury, thallium, vanadium, zinc;
- chloride (Cl^-), sulphate (SO_4^{2-}), fluoride (F^-);
- total organic carbon (TOC);
- pH-value, electrical conductivity, odour, colour, turbidity, and tendency to produce foam.

The parameters shall be analysed with an appropriate standardised test method (this test method has a suitable method detection limit compared to the limit value).

Expression of result(s)

The test methods for the analysis of the parameters including method detection limits shall be stated in the ETA.

Measured concentration of the leaching test in accordance with EN 16637-2 of hardened mix shall be expressed per step for each parameter in µg/L and mg/m². Additionally, the cumulatively released quantities shall be expressed for each parameter in mg/m² and shall be stated in the ETA.

2.2.9 Water-soluble hexavalent chromium

Purpose of the assessment

Determination of water-soluble hexavalent chromium content in the blended cement.

Assessment method

The determination of the water-soluble hexavalent chromium content shall be determined in accordance with EN 196-10, Annex A.

The determination of water-soluble hexavalent chromium content shall be carried out in duplicate.

The water-soluble hexavalent chromium content shall not exceed 2 ppm in accordance with Regulation (EC) no. 1907/2006 of 18 December 2006.

Expression of result(s)

The average content of water-soluble hexavalent chromium (ppm) shall be stated in the ETA.

2.2.10 Compressive strength of the blended cement mixed with aggregates (at 1, 2, 7, 28, and 90 days)

Purpose of the assessment

Assessment of the development of the compressive strength of the blended cement mixed with aggregates.

Assessment method

The blended cement shall be mixed with water and limestone aggregates. Mix A (see

Table 2.2.10.1) shall be used[6].
The mix shall be poured in 15 cylinders (diameter: 11 cm x height: 22 cm) {reference shape} or 15 cubes (edge: 10 cm). All specimens shall be demoulded at 24 h and cured under water until used. At 1, 2, 7, 28 and 90 days, 3 specimens shall be taken out for the compression test. The compression test shall be performed in accordance with EN 12390-3. The intended load-bearing surfaces shall be prepared by grinding (see EN 12390-3, Clause A.2) {reference method} or capping by sulphur mixture (see EN 12390-3, Clause A.4).

6 Due to its composition, the density and water demand of the blended cement (according to Manufacturer's utilisation instruction manual) may be different from those assumed in the composition of Mix A, which shall therefore be adapted to maintain 1 m^3 of mix with a minimum S3-class consistency. If the density of blended cement is different, maintaining 350 kg of blended cement per m^3 will result in a different paste volume. Similarly, if the water demand of the blended cement is different, maintaining an S3-class consistency by adjusting water-cement ratio will result in a different paste volume. In all cases, to maintain 1 m^3 of mix, the volume of paste shall be completed by the volume of aggregates. Depending on the density of the aggregates, the mass of each aggregate class shall be adjusted while keeping the relative proportion of each class constant.

Table 2.2.10.1 Composition of mix for compressive strength

Mix identification	Composition per m^3
Mix A[a]	Blended cement content: B = 350 kg Limestone aggregate (0/4 mm) = 920 kg Limestone aggregate (4/10 mm) = 423 kg Limestone aggregate (10/20 mm) = 684 kg Aggregates in accordance with EN 12620 and complying with EN 480-1, Clause 4.2 requirements shall be used. $W_{Eff}/B = 0.34$ Water reducing admixture (if necessary) to achieve a minimum consistence class S3[b].

(a) The Mix A is defined on the assumption that the density of the blended cement is 2850 kg/m^3 and the density of limestone aggregate is 2720 kg/m^3.

(b) Consistence class in accordance with EN 206, Clause 4.2.1, Table 3; evaluation in accordance with EN 12350-2.

Expression of result(s)

In the ETA, the following information shall be started:

- Mix used (type and size distribution of each type of aggregate and its content, blended cement content, effective water to blended cement ratio, admixture dosage and nature);
- Shape of the specimens;
- Preparation method.

For each period (1, 2, 7, 28 and 90 days), the mean of the results (in MPa) of the 3 compression tests.

2.2.11 Shrinkage of the blended cement mixed with sand

Purpose of the assessment

Determination of the length change of blended cement mixed with sand.

Assessment method

The shrinkage of the blended cement mixed with sand shall be determined in accordance with EN 12617-4, Clause 6, with the following deviations:

- The mix composition shall be: 1350 g of sand, 500 g of blended cement, 200 g of water, and superplasticizer (if necessary, flow ≥ 120 mm measured in accordance with EN 1015-3);
- After demoulding (24 h), the specimens shall be stored in an atmosphere of (50 ± 5) % humidity at (20 ± 2) °C;
- The measurement shall be done 28 days after demoulding.

Expression of result(s)

The shrinkage of the blended cement mixed with sand [mm/m] shall be stated in the ETA.

2.2.12 Shrinkage of the blended cement mixed with aggregates

Purpose of the assessment

Assessment of the development of shrinkage of blended cement mixed with aggregates.

Assessment method

The blended cement shall be mixed with water and limestone aggregates. Mix A (see

Table 2.2.10.1) shall be used[6].

The shrinkage of the blended cement mixed with aggregates shall be determined in accordance with EN 12390-16, using method A in Clause 3.5 for the positioning of the measuring points, and using a reference bar for the measuring (Clause 5.2.3 of EN 12390-16).

Expression of result(s)

In the ETA, the following information shall be stated:

- Mix used (type and size distribution of each type of aggregate and its content, blended cement content, effective water to blended cement ratio, admixture dosage and nature);
- For each specimen, the shape and the dimension of the specimens, the evolution of total shrinkage strain [mm/m] versus time.

2.2.13 Creep (total, autogenous and drying) of the blended cement mixed with aggregates in compression

Purpose of the assessment

Assessment of the development of compressive creep of the blended cement mixed with aggregates.

Assessment method

The blended cement shall be mixed with water and limestone aggregates. Mix A (see

Table 2.2.10.1) shall be used[6].

The specimens shall be prepared in accordance with EN 12390-17, Clause 6 and Clause 7.

The loading starts at 28 days after casting.

The compressive strength f_c of mix shall be determined on companion specimens in accordance with EN 12390-3. Cylinder (diameter = 11 cm × height = 22 cm) specimens shall be used for creep, shrinkage and f_c. The compressive creep (total, autogenous and drying) of mix shall be determined in accordance with EN 12390-17, with the positioning of the measuring points in accordance with Clause 3.6, Figure 1b. The measuring (tolerances in accordance with Clause 5.3.1 of EN 12390-17) shall be performed by using either displacement gauges, or both studs (in accordance with Clause 5.5) and a reference bar (in accordance with Clause 5.3.3). The two methods are equivalent.

For each specimen, the total, autogenous and drying creep shall be calculated in accordance with EN 12390-17, Clause 8.1.

Expression of result(s)

In the ETA, the following information shall be stated:

- Mix used (type and size distribution of each type of aggregate and its content, blended cement content, effective water to blended cement ratio, admixture dosage and nature).
- For each specimen, the shape and the dimension of the specimens, the total, autogenous and drying creep [mm/m] versus time shall be calculated in accordance with EN 12390-17, Clause 8.1.

2.2.14 Resistance against sulphate at 20 °C of the blended cement

Purpose of the assessment

Assessing the possible damage caused by sulphate at standard temperature for the blended cement mixed with aggregates.

Assessment methods

The resistance of the blended cement shall be determined on a blended cement mixed with aggregates (reference method) or alternatively on a blended cement mixed with sand (alternative method).

- Method A (reference method): resistance against sulphate of blended cement mixed with aggregates

  Resistance against sulphate shall be assessed by immersion of specimens in a sulphate-rich solution, according to Annex A, Clause A.1.

The blended cement shall be mixed with water and limestone aggregates. Mix A (see

Table 2.2.10.1) shall be used[6].

- Method B: resistance against sulphate of blended cement mixed with sand

  The sulphate resistance of the blended cement shall be determined according to Annex A, Clause A.2.

Expression of result(s)

The method shall be stated in the ETA.

- Method A (reference method): resistance against sulphate of the blended cement mixed with aggregates

  In the ETA, the following information shall be stated:

  - Mix used (type and size distribution of each type of aggregate and its content, blended cement content, effective water to blended cement ratio, admixture dosage and nature).
  - The average values of the length change (Δl_n) after each measurement (see Clause A.1.3) shall be given in the ETA.
  - Resistance against sulphate, expressed as an average elongation after permanent storage in sulphate solution (Δls in ‰, according to Annex A, Clause A.1) shall be stated in the ETA.
  - The average value of the ratio of mass change to the initial volume of the specimen after permanent storage in the sulphate solution Δm_{sn} [kg/m³] shall be stated in the ETA.
  - In addition, a detailed description of the specimens in view of cracks (e.g. photo with caption) after testing – if any – shall be stated in the ETA.

- Method B: resistance against sulphate of the blended cement mixed with sand

  The average values of the length difference [mm/m] for the blended cement, test solution (0.444 % Na_2SO_4-solution and saturated $Ca(OH)_2$-solution), storage temperature (T = 20 °C) and storage time (t_i = 13, 26, 39, 52, 65, 78, 91, and 104 weeks) shall be given in the ETA:

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

  The calculated expansion of the length [mm/m], storage temperature (T = 20 °C) and storage time (t_i = 13, 26, 52, 65, 78, 91, and 104[7] weeks) shall be given in the ETA:

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

  The average value of the dynamic modulus of elasticity (MPa), storage solution (0.444 % Na_2SO_4-solution and saturated $Ca(OH)_2$-solution), storage temperature (T = 20 °C) and storage time (t_i = 13, 26, 39, 52, 65, 78, 91, and 104 weeks) and also the initial measurement (after pre-storage t = 0) shall be given in the ETA:

  - $E_{d,NS,(ti,T)}$, $E_{d,CH,(ti,T)}$ and $E_{d,0}$

  The average value of mass of the specimens [kg] for each tested cement, storage solution (0.444 % Na_2SO_4-solution and saturated $Ca(OH)_2$-solution), storage temperature (T = 20 °C) and storage time (t_i = 13, 26, 39, 52, 65, 78, 91, and 104 weeks) and also the initial measurement (after pre-storage t = 0) shall be given in the ETA:

  - $w_{NS,(ti,T)}$, $w_{CH,(ti,T)}$ and w_0

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

2.2.15 Resistance against sulphate at 5 °C of the blended cement

Purpose of the assessment

Assessing the possible damage caused by sulphate at low temperature for the blended cement.

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[7] The test shall be carried out until no significant increase in strain can be seen in the specimens stored in the 0.444% Na_2SO_4 solution.

Assessment methods

- Method A (reference method): resistance against sulphate at 5 °C of the blended cement mixed with aggregates

The blended cement shall be mixed with water and limestone aggregates. Mix A (see

Table 2.2.10.1) shall be used[6].

The resistance of mix against sulphate shall be assessed according to Clause 2.2.14, Method A with the following deviations:

- The storage temperature shall be 5 °C;
- The average values of the length difference and mass shall be performed at the same time but the following time shall be added: 91, 119, 147, 182, 210, 238, and 273 days.

➢ Method B: resistance against sulphate at 5 °C of the blended cement mixed with sand

The resistance against sulphate shall be assessed according to Clause 2.2.14, Method B with the following deviation:

- The storage temperature shall be 5 °C.

Expression of result(s)

The method shall be stated in the ETA.

➢ Method A (reference method): resistance against sulphate at 5 °C of the blended cement mixed with aggregates

In the ETA, the following information shall be stated:

- Mix used (type and size distribution of each type of aggregate and its content, blended cement content, effective water to blended cement ratio, admixture dosage and nature).
- Resistance against sulphate, expressed as an average elongation [‰] after permanent storage in sulphate solution shall be stated in the ETA. In addition, a detailed description of the specimens in view of cracks (e.g. photo) after testing – if any.

➢ Method B: resistance against sulphate at 5 °C of the blended cement mixed with sand

Expansion of length ($\Delta l_{ti,T}$ in mm/m), mean length difference of the flat prism in the sulphate solution ($\Delta l_{NS,(ti,T)}$ in mm/m) and mean length difference of the flat prism in a saturated $Ca(OH)_2$ solution ($\Delta l_{CH,(ti,T)}$ in mm/m) shall be presented according to Clause 2.2.14, Method B. In addition, a detailed description of the specimens in view of cracks (e.g. photo with caption) after testing – if any – shall be stated in the ETA.

2.2.16 Resistance to chloride penetration, unidirectional diffusion, of the blended cement mixed with aggregates

Purpose of the assessment

Assessment of the chloride penetration at specified age in the blended cement mixed with aggregates

Assessment method

The blended cement shall be mixed with water and limestone aggregates. Mix A (see

Table 2.2.10.1) shall be used[6].

Resistance against chloride shall be assessed in accordance with EN 12390-11 with the following specifications:

- A curing time of 90 days (EN 12390-11, Clause 6.1)
- Sealing surfaces other than the surface to be exposed (EN 12390-11, Clause 6.2.2.a).
- Immersion of the specimen (EN 12390-11, Clause 6.2.3) during 182 days.
- The thickness of layers shall be 1 mm until the end of the profile (EN 12390-11, Clause 7.5).
- The chloride content shall be determined in accordance with EN 14629, Clause 4.3.4.2.

Expression of result(s)

In the ETA, the following information shall be stated:

- Mix used (type and size distribution of each type of aggregate and its content, blended cement content, effective water to blended cement ratio, admixture dosage and nature).
- Resistance against chlorides [m^2/s] shall be expressed as the chloride diffusion coefficient (D_{nss}) in conformity with EN 12390-11, Clause 8.

2.2.17 Chloride migration in the blended cement mixed with aggregates

Purpose of the assessment

Assessment of chloride migration in the blended cement mixed with aggregates.

Assessment method

The blended cement shall be mixed with water and limestone aggregates. Mix A (see

Table 2.2.10.1) shall be used[6].

Resistance against chloride shall be determined in accordance with EN 12390-18 with the following deviation:

- A curing time of 90 days (EN 12390-18, Clause 7.2)
- Vacuum saturation of test specimen shall be performed with a solution of [NaOH] = 0.1 M during 72 h (EN 12390-18, Clause 8.1),
- Anolyte: [NaOH] = 0.1 M and catholyte: [NaOH] = 0.1 M and [NaCl] = 0.5 M (EN 12390-18, Clause 6).

Expression of result(s)

In the ETA, the following information shall be stated:

- Mix used (type and size distribution of each type of aggregate and its content, blended cement content, effective water to blended cement ratio, admixture dosage and nature).
- Chloride migration coefficient [m^2/s] shall be expressed in accordance with (EN 12390-18, Clause 9).

2.2.18 Basicity of the pore water solution in the blended cement mixed with aggregates

Purpose of the assessment

Determination of the basicity of the pore water solution after hydration of the blended cement to estimate the corrosion protection of reinforced steel.

Assessment method

The blended cement shall be mixed with water and limestone aggregates. Mix A (see

Table 2.2.10.1) shall be used[6].

The assessment shall be in accordance with test method given in Annex B.

Expression of result(s)

In the ETA, the following information shall be stated:

- Mix used (type and size distribution of each type of aggregate and its content, blended cement content, effective water to blended cement ratio, admixture dosage and nature).
- The pH-value of the pore water solution.

2.2.19 Carbonation rate of the blended cement mixed with aggregates

Purpose of the assessment

Assessment of the carbonation rate of the blended cement mixed with aggregates at atmospheric levels of carbon dioxide.

Assessment method

The blended cement shall be mixed with water and limestone aggregates. Mix A (see

Table 2.2.10.1) shall be used[6].

The carbonation rate shall be measured in accordance with EN 12390-10, Clause 6.3, with the natural exposure site method.

Expression of result(s)

In the ETA, the following information shall be stated:

- Mix used (type and size distribution of each type of aggregate and its content, blended cement content, effective water to blended cement ratio, admixture dosage and nature).
- The carbonation rate shall be expressed in accordance with EN 12390-10, Clause 8.

2.2.20 Resistance to carbonation of the blended cement mixed with aggregates in accelerated test

Purpose of the assessment

Assessment of carbonation kinetics of the blended cement mixed with aggregates in accelerated conditions.

Assessment method

The blended cement shall be mixed with water and limestone aggregates. Mix A (see

Table 2.2.10.1) shall be used[6].

The carbonation resistance shall be assessed in accordance with EN 12390-12 with the following deviations:

- A curing time of 90 days (EN 12390-12, Clause 6.2)
- The specimen shall be cylinder (diameter = 11 cm × height = 11 cm) in accordance with (EN 12390-12, Clause 6.2) obtained by sawing each casted cylinder (diameter = 11 cm × height = 22 cm) in half. Each flat surface of the cylinders shall be protected by either using an aluminium adhesive foil or epoxy resin to ensure only radial diffusion.
- The pre-treatment shall be changed as follows (EN 12390-12, Clause 6.2): after the curing time, the specimens shall be dried in an oven at 45 °C for 14 days. Then, the specimens shall be kept for 7 days at T = 20 °C and RH = 65 %.
- The atmospheric conditions during test shall be T = (20 ± 2) °C, RH = (65 ± 5) % and [CO_2] = 3 % (EN 12390-12, Clause 5).

Expression of result(s)

In the ETA, the following information shall be stated:

- Mix used (type and size distribution of each type of aggregate and its content, blended cement content, effective water to blended cement ratio, admixture dosage and nature).
- The carbonation depth (d_k) shall be expressed in accordance with EN 12390-12.

2.2.21 Resistance to alkali-silica reaction of the blended cement mixed with reactive aggregates

Purpose of the assessment

Assessment of the longitudinal expansion kinetics in an alkaline environment of the blended cement mixed with aggregates reactive to the alkali-silica reaction.

Assessment method

The assessment shall be carried out in accordance with test method given in Annex C.

Expression of result(s)

In the ETA, the following information shall be stated:

- Mix used (type and size distribution of each type of aggregate and its content, blended cement content, effective water to blended cement ratio, admixture dosage and nature).
- The longitudinal expansion kinetics shall be expressed according to Annex C, Clause C.2.6.

3 ASSESSMENT AND VERIFICATION OF CONSTANCY OF PERFORMANCE

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

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

The system(s) is (are): 1+

3.2 Tasks of the manufacturer

The cornerstones of the actions to be undertaken by the manufacturer of the product in the procedure of assessment and verification of constancy of performance are laid down in Table 3.2.2.1.

3.2.1 Control of raw materials by manufacturer

The raw materials for the production of the blended cement shall be subject to control by the manufacturer before acceptance. Check of raw materials shall include control of the inspection documents presented by the suppliers of the initial materials (comparison of the trade name, producer and internal requirements on the product characteristics). Regarding the components he buys from the market with Declaration of Performance (DoP), the manufacturer shall take into account the one issued by the manufacturer of that component. No retesting is necessary.

3.2.1.1 Control plan for the manufacturer (part concerning raw materials); 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	GGBS	Clause 3.4.1.1	According to control plan	1	Each delivery
2	Pozzolanic material (natural (P)) and natural calcined pozzolana (Q)	Clause 3.4.1.2	According to control plan	1	Each delivery
3	Portland cement clinker	Clause 3.4.1.3	According to control plan	1	Each delivery
4	Limestone (L, LL) or dolomitic limestone	Clause 3.4.1.4	According to control plan	1	Each delivery
5	Calcium sulphate	Clause 3.4.1.5	According to control plan	1	Each delivery

3.2.2 Control of the blended cement composition

The blended cement composition and properties shall be controlled by the manufacturer of the product in the procedure of assessment and verification of constancy of performance, as defined in Table 3.2.2.1.

Table 3.2.2.1 Control plan for the manufacturer (part concerning blended cement); cornerstones

No	Subject/type of control	Test or control method	Criteria, if any	Minimum number of samples	Minimum frequency of control
	Factory production control (FPC) [including testing of samples taken at the factory in accordance with a prescribed test plan]				
1	Early strength	Clause 2.2.3	According to control plan	1	2/week[8] 4/week[9]
2	Standard strength (28d)	Clause 2.2.4	According to control plan	1	2/week[8] 4/week[9]
3	Long-term strength	Clause 2.2.5	According to control plan	1	1/month[8] 1/week[9]
4	Initial setting time	EN 196-3, Clause 6.2	According to control plan	1	2/week[8] 4/week[9]
5	Final Setting time	EN 196-3, Clause 6.3	According to control plan	1	2/week[8] 4/week[9]
6	Soundness	EN 196-3, Clause 7	According to control plan and < to 10 mm	1	1/week[8] 4/week[9]
7	Heat of hydration	Clause 2.2.6	According to control plan < 270 J/g	1	1/month[8] 1/week[9]
8	Sulphate content	Clause 2.2.7	According to control plan and ≤ 4.0 % in mass	1	2/week[8] 4/week[9]
9	Chloride content	EN 196-2, Clause 4.5.16	According to control plan and ≤ 0.10 % in mass	1	2/month[8] 1/week[9]
10	Blended cement composition[10]	EN 196-2 Clause 4 (reference method) or Clause 5	In accordance with specification deposited at the TAB.	1	1/month[8] 1/week[9]

8 In case of routine situation

9 Initial period (3 month)

10 The blended cement composition shall meet the requirements specified above. The limiting quantities of the main constituents (GGBS, pozzolanic material, clinker and filler) specified above are reference values to be met by the average composition calculated from the spot samples taken in the control period. For single results, maximum deviations of -3 points at the lower and +3 points at the higher reference value are allowed. Suitable procedures during production and appropriate verification methods to ensure conformity to this requirement shall be applied and documented.

3.3 Tasks of the notified body

The cornerstones of the actions to be undertaken by the notified body in the procedure of assessment and verification of constancy of performance for the blended cement are laid down in Table 3.3.1.

Table 3.3.1 Control plan for the notified body; cornerstones

No	Subject/type of control	Test or control method	Criteria, if any	Minimum number of samples	Minimum frequency of control
Initial inspection of the manufacturing plant and of factory production control					
1	In accordance with EN 197-2, Clause 5.2	See FPC, Table 3.2.2.1	Control Plan + Quality documentation	-	1/year
Continuous surveillance, assessment and evaluation of factory production control					
2	In accordance with EN 197-2, Clause 5.3	See FPC, Table 3.2.2.1	Control Plan + Quality documentation	-	1/year
Audit-testing of samples taken by the notified product certification body at the manufacturing plant or at the manufacturer's storage facilities					
3	In accordance with EN 197-2 Clause 5.4	See FPC, Table 3.2.2.1	Control Plan	1	6/year

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

3.4.1 Control of raw materials by manufacturer

The raw materials for the production of the blended cement shall be subject to control by the manufacturer before acceptance. Check of raw materials shall include control of the inspection documents presented by the suppliers of the raw materials (comparison of the trade name, producer and internal requirements on the blended cement characteristics).

3.4.1.1 GGBS

GGBS shall be compliant with EN 15167-1 and controlled by checking the inspection document type 3.1 in accordance with EN 10204 for the following properties:

- Constituents (Clause 5.4 of EN 15167-1);
- Chemical requirements (Clause 5.2 of EN 15167-1);
- Initial setting time (Clause 5.3.2.2 of EN 15167-1);
- Durability (Clause 5.4.1 of EN 15167-1);
- Release of dangerous substances (Clause 5.4.2 of EN 15167-1);
- The activity index (expressed in accordance with EN 15167-1, Clause 5.3.2.3) at 7 days and at 28 days are not less than 65% and 85 % respectively;
- The specific surface determined in accordance with the air permeability method (Blaine) specified in EN 196-6, Clause 4, shall not be less than 420 m^2/kg;
- $(CaO + MgO)/SiO_2 \geq 1.2$.

3.4.1.2 Pozzolanic material (natural (P)) and natural calcined pozzolana (Q)

Pozzolanic material (natural (P)) and natural calcined pozzolana (Q) shall be compliant with EN 197-1, Clause 5.2.3 and controlled by checking the inspection document type 3.1 in accordance with EN 10204 for the following properties:

- Density in accordance with EN 196-6;

- Fineness in accordance with EN 196-6;
- Constituents (Clause 5 of EN 196-2);
- Loss on ignition (Clause 5.4 of EN 196-2);
- Chloride (Clause 4.5.16 of EN 196-2);
- Soundness (Clause 7 of EN 196-3);
- Total alkali content expressed in Na_2O_{eq} (Clause 4.5.19 of EN 196-2);
- Sulphate (Clause 4.4.2 of EN 196-2);
- Reactive silica (Clause 4.5.3 of EN 196-2);
- Activity index in accordance with EN 196-1;
- Methylene blue value in accordance with EN 933-9;
- Water content in accordance with EN 196-3.
- Organic carbon (natural pozzolana only) in accordance with EN 13639
- Granulometry in accordance with EN 933-10;
- Heat of hydration and bound water content determined in accordance with prEN 196-12 at 7 days.

3.4.1.3 Portland cement clinker

Portland cement clinker shall be compliant with EN 197-1, Clause 5.2.1 and controlled by checking the inspection document type 3.1 in accordance with EN 10204 for the following properties:

- Fineness in accordance with EN 196-6;
- Loss on ignition (Clause 5.4 of EN 196-2);
- Constituents (Clause 5 of EN 196-2).

3.4.1.4 Limestone (L, LL) or dolomitic limestone

Limestone (L, LL) or dolomitic limestone shall be compliant with EN 197-5, Clause 4 and controlled by checking the inspection document type 3.1 in accordance with EN 10204 for the following properties:

- Particle density in accordance with EN 1097-7;
- Fineness in accordance with EN 196-6;
- $CaCO_3$ and $MgCO_3$ content in accordance with EN 196-2;
- Chloride (Clause 4.5.16 of EN 196-2);
- Sulphate (Clause 10 of EN 1744-1);
- Total sulphur (Clause 11 of EN 1744-1);
- Total organic matter content in accordance with EN 13639;
- Clay content determined by the methylene blue test in accordance with EN 933-9;
- Total SiO_2 (Clause 5 of EN 196-2);
- Total alkali content expressed in Na_2O_{eq} (Clause 4.5.19 of EN 196-2);
- Granulometry in accordance with EN 933-10;
- Activity index in accordance with EN 196-1;
- Moisture in accordance with EN 1097-5.

3.4.1.5 Calcium sulphate

Calcium sulphate shall be compliant with EN 197-1, Clause 5.4 and controlled by checking the inspection document type 3.1 in accordance with EN 10204 for the following properties:

- $CaSO_4$ content (Clause 5.1 of EN 13454-2).

4 REFERENCE DOCUMENTS

EN 196-1:2016	Methods of testing cement - Part 1: Determination of strength.
EN 196-2:2013	Methods of testing cement - Part 2: Chemical analysis of cement
EN 196-3:2016	Methods of testing cement - Part 3: determination of setting times and soundness
EN 196-6:2018	Methods of testing cement - Part 6: Determination of fineness
EN 196-9:2010	Methods of testing cement - Part 9: Heat of hydration — Semi-adiabatic method
EN 196-10:2016	Methods of testing cement - Part 10: Determination of the water- soluble chromium (VI) content of cement
EN 197-1:2011	Cement - Part 1: Composition, specifications and conformity criteria for common cements
EN 197-2:2020	Cement - Part 2: Conformity evaluation
EN 197-5:2021	Cement - Part 5: Portland-composite cement CEM II/C-M and Composite cement CEM VI
EN 206:2013+A2:2021	Concrete - Specification, performance, production and conformity
EN 480-1:2023	Admixtures for concrete, mortar and grout — Test methods — Part 1: Reference concrete and reference mortar for testing
EN 933-9:2022	Tests for geometrical properties of aggregates – Part 9: assessment of fines – Methylene blue test
EN 933-10:2009	Tests for geometrical properties of aggregates – Part 10: assessment of fines – Grading of filler aggregates (air jet sieving)
EN 1015-3:1999 +A1:2004+A2:2006	Methods of test for mortar for masonry. Part 3: Determination of consistence of fresh mortar (by flow table)
EN 1097-5:2008	Tests for mechanical and physical properties of aggregates – Part 5: determination of the water content by drying in a ventilated oven
EN 1097-7:2022	Tests for mechanical and physical properties of aggregates – Part 7: determination of the particle density of filler – Pyknometer method
EN 1744-1:2009+A1:2012	Test for chemical properties of aggregates – Part 1: chemical analysis
EN 10204:2005	Metallic products – Types of inspection documents
EN 12350-2:2019	Testing fresh concrete - Part 2: slump test
EN 12390-2:2019	Testing hardened concrete - Part 2: making and curing specimens for strength tests
EN 12390-3:2019	Testing hardened concrete - Part 3: compressive strength of test specimens
EN 12390-10:2018	Testing hardened concrete - Part 10: determination of the carbonation resistance of concrete at atmospheric levels of carbon dioxide
EN 12390-11:2015	Testing hardened concrete - Part 11: Determination of the chloride resistance of concrete, unidirectional diffusion
EN 12390-12:2020	Testing hardened concrete - Part 12 : determination of the carbonation resistance of concrete – Accelerated carbonation method
EN 12390-16:2019	Testing hardened concrete - Part 16: determination of the shrinkage of concrete
EN 12390-17:2019	Testing hardened concrete - Part 17: determination of creep of concrete in compression
EN 12390-18:2021+A1:2024	Testing hardened concrete - Part 18: determination of the chloride migration coefficient

EN 12617-4: 2002	Products and systems for the protection and repair of concrete structures. Test methods. Determination of shrinkage and expansion
EN 12620:2002+A1:2008	Aggregates for concrete
EN 13454-2:2019	Binders and factory made mixtures for floor screeds based on calcium sulphate – Part 2: test methods
EN 13639:2017	Determination of total organic carbon in limestone
EN 14146:2004	Natural stone test methods - Determination of the dynamic modulus of elasticity (by measuring the fundamental resonance frequency)
EN 14629:2007	Products and systems for the protection and repair of concrete structures. Test methods. Determination of chloride content in hardened concrete
EN 14647:2005/AC:2006	Calcium aluminate cement - Composition, specifications and conformity criteria
EN 15167-1:2006	Ground granulated blast-furnace slag for use in concrete, mortar and grout - Part 1: Definitions, specifications and conformity criteria
EN 16637-2:2023	Construction Products - Assessment of release of dangerous substances - Part 2: Horizontal dynamic surface leaching test
EN 196-12:2024	Methods of testing cement – Part 12: Reactivity of cement constituents – Heat of hydration and bound water content methods

ANNEX A RESISTANCE TO SULPHATES

A.1 Method A: Resistance to sulphate of blended cement mixed with aggregates – principle and reference[11]

In this test, specimen cores cured under water for 90 days shall be subjected to 4 successive cycles each comprising drying (described in Clause A.1.3) at (50 ± 2) °C and soaking at (20 ± 2) °C with a solution of Na_2SO_4 at 50 g/L (equivalent to 33.8 g/L of SO_4). After these four cycles, the samples are stored 56 days in the sulphate solution.

The length and mass of each core shall be measured regularly. The test lasts 4 months with a 90-day curing. The cores shall be taken from laboratory specimens (2 cubes with edge of 150 mm).

A.1.1 Laboratory and equipment

- Laboratory regulated at (20 ± 2) °C
- Stainless steel studs to be glued
- Balance of precision 0.01 g accurate to within 0.03 g
- Calliper with a resolution of 0.01 mm accurate to 0.05 mm.
- Comparator with resolution 0.001 mm accurate to 0.002 mm.
- Ventilated oven, regulated at (50 ± 2) °C with good air renewal in and around the oven (the oven shall be located more than 20 cm away from a wall or any other device).

A.1.2 Test specimens

The specimens shall be two cubes with edge of 150 mm for each mix.

Between the 87th and 89th days, sample 6 traversing cores of (28 ± 1) mm diameter from the lateral faces of the two cubes.

Before drilling, grind the two opposites lateral faces so that they are parallel to each other. Drill to extract 3 cores per cube (see Figure A.1.2.1). Use a driller in good condition and of adequate power.

Ensure a regular advance of the driller, do not "force" on the driller, which would possibly induce micro-cracking of the cores and an irregular cutting. The length of the cores shall be comprised between 145 mm and 150 mm.

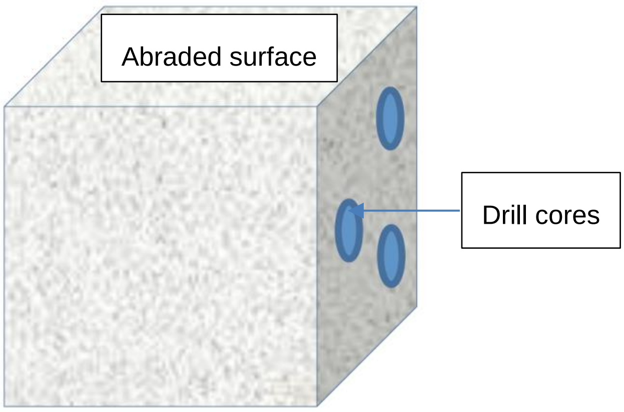

Figure A.1.2.1 Illustration of the specimen

With the calliper, measure the initial length (l) of the 6 cores in mm and their diameter (d) in mm at 3 locations minimum in order to give an average length l (tolerance for (l) and (d): 0.1 mm).

Store the cores in boxes at (20 ± 2) °C and between 70 % and 90 % RH.

[11] This annex presents the complete assessment method for assessing the product's performance. For transparency purpose, it is specified that this method is adapted from the Swiss standard SIA 262-1, Annex D: 2013, since there is currently no existing European standard available on the subject

On day 90, glue the stainless steel studs to both ends of the cores with an epoxy resin using a suitable centring device. Indicate the location of the stainless steel studs with a pencil. The part of the surface that is covered by the stud and the glue shall not exceed 15 mm of diameter.

A.1.3 Test procedure

One hour before starting the test, immerse the cores in water at (20 ± 2) °C for (60 ± 10) min then measure the initial length (l_0) in mm to the nearest 0.001 mm using the 145 mm invar bar. Check this bar and the comparator with a reference bar regularly.

The Cycle 1 consists of the following steps:

- At t_0 (test beginning) of the test, place the cores in a ventilated chamber at (50 ± 2) °C for (120 ± 2) hours (5 days). The cores shall be placed on small triangular rods (10 mm high) and perforated shelves to allow homogeneous air circulation around the specimen.
- At the end of this time take the cores out of the oven, put them to cool at (20 ± 2) °C for 1 hour in a waterproof box or a desiccator with a desiccant (RH < 5 % for example: dried silica gel or magnesium perchlorate) then measure their mass (m_{T1}) in g with a 0.01 g accuracy
- Then immerse the 6 cores for (48 ± 2) h in a 50 g/L Na_2SO_4 solution (equivalent to 33.8 g/L of SO_4). The solution shall be prepared by pouring 50 g of Na_2SO_4 into 950 g of demineralized water. The volume of solution shall be 2.4 litres. The cores shall be always completely immersed. Any loss of solution shall be compensated by an additional volume of solution. The boxes shall have a waterproof cover. The cores shall be at least 10 mm apart from the bottom of the box, the walls and each other. Put only a series of 6 cores per box.
- At the end of the (48 ± 2) h, remove the cores from the solution and wipe them dry, measure their length (l_1) in mm at 0.001 mm near and their weight (m_{s1}) in g at 0.01 g accuracy.

Cycles 2 to 4:

- dry the cores at (50 ± 2) °C for (120 ± 2) h as mentioned above, then let them cool off at (20 + 2) °C in a waterproof box or a desiccator with a desiccant (HR < 5 %) then measure their mass m_{T2} (respectively m_{T3} and m_{T4}) in g with a 0.01 g accuracy.
- After the cooling, immerse the cores for (48 ± 2) h in the 50 g/L Na_2SO_4 solution (equivalent to 33.8 g/L of SO_4). The volume of solution shall be 2.4 litres. The cores shall be completely immersed. The boxes shall have a waterproof cover. The cores shall be at least 10 mm apart from the bottom of the box, the walls and each other. Put only a series of 6 cores per box.
- At the end of the (48 ± 2) h, remove the cores from the solution and wipe them dry, measure their length l_2 (respectively l_3 and l_4) in mm at 0.001 mm near and their weight m_{s2} (respectively m_{s3} and m_{s4}) in g at 0.01 g accuracy.

After the 4th cycle of measuring the mass and length of the cores, put the specimens back in the sulphate solution for 56 days. At days 7, 14, 28, 42, and 56, remove the cores, wipe them off and measure their length and mass l_5 and m_{s5} at 7 days, l_6 and m_{s6} at 14 days, l_8 and m_{s8} at 28 days, l_{10} and m_{s10} at 42 days, l_{12} and m_{s12} at 56 days with an accuracy of 0.001 mm and 0.01 g.

A.1.4 Test results

Calculation of the initial volume of the cores:

$$V_0 = \frac{\pi l d^2}{4 \times 10^9}$$

Where:

- d is the diameter of the core [mm]
- l is the length of the core [mm]

Calculation of the length change after n weeks, with $n \in \{1, 2, 3, 4, 5, 6, 8, 10, 12\}$

$$\Delta l_n = \frac{l_n - l_0}{l} \times 1000$$

Where:

- l_n is the measured length [mm] after n weeks
- l_0 is the measured length [mm] before the first cycle
- l is the length [mm] of the core before the studs are glued on it

Calculation of sulphatic elongation after permanent storage in sulphate solution: Δl_s

$$\Delta l_s = \Delta l_{12} - \Delta l_4$$

Calculation of the mass change during the cycles of immersion/cooling: $\Delta m_{sn,cycle}$

$$\Delta m_{sn,cycle} = \frac{m_{sn} - m_{Tn}}{V_0} \quad [\mathrm{kg/m^3}]$$

Where:

- m_{sn} is the mass [kg] after storage in the sulphate solution after n cycles, n = 1 to 4;
- m_{Tn} is the mass [kg] after drying after n cycles, n = 1 to 4;

Calculation of the mass change after n weeks of permanent storage in the sulphate solution: $\Delta m_{sn,storage}$.

$$\Delta m_{sn,storage} = \frac{m_{sn} - m_{sv}}{V_0} \quad [\mathrm{kg/m^3}]$$

Where

- m_{sn} is the mass [kg] after storage in the sulphate solution after n cycles, n = 5, 6, 8, 10, 12;
- m_{sv} is the mass [kg] after drying after the previous measure;

Note any problems and signs of degradation observed during the test (cracking of the cores, detachment of the aggregates, detachment of the studs, etc.).

The final result of the test is the average elongation after permanent storage in sulphate solution (Δl_s) on the 6 test pieces (or less if some test pieces are no longer measurable in end of test). In case of extreme high and asymmetric values compared to the mean, the mean can be replaced by the median of the results.

Repeatability of 0.02 ‰, reproducibility according to expansion level (see Table A.1.4.1).

Table A.1.4.1 Precision data of expansion levels

Expansion level [‰]	standard deviation of reproducibility
0.20	0.05
0.77	0.22
1.79	0.61

Note: In case the Δl_s is greater than 1.2 ‰, the appropriate behaviour of the product cannot be guaranteed.

A.2 Method B: Resistance to sulphate of the blended cement mixed with sand – Flat prism method SFPMm - principle and reference

A.2.1 General description of the test method

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

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

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

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

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

A.2.2 Cements

The sulphate resistance shall be tested on specimens made of the blended cement mixed with sand with a lower w/c-ratio on the basis of EN 196-1 with the blended cement.

A.2.3 Making of test specimens

The Mix shall be produced in accordance with EN 196-1 with the following deviations:

- 1350 g of sand,
- 500 g of blended cement,
- 200 g of water.

24 flat prisms with the dimensions 10 mm × 40 mm × 160 mm (12 with and 12 without measuring stud) shall be made in accordance with EN 196-1 and be compacted on the vibrating table. Measuring stud shall be cast into the specimen.

A.2.4 Storage of test specimens

The specimens shall be stored for (48 ± 2) hours in the mould, protected from drying at a temperature of (20 ± 2) °C and a relative air humidity greater than 95 %.

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

After demoulding the flat prisms shall be pre-stored until the age of 28 days, on edge, standing on gratings in saturated calcium hydroxide ($Ca(OH)_2$)-solution at (20 ± 2) °C.

After pre-storage:

- For the Na_2SO_4 storage (NS), 3 flat prisms with measuring stud and 3 flat prisms without measuring stud will be stored on edge, standing on gratings in the 0.444 % Na_2SO_4-solution at (5 ± 2) °C (Na_2SO_4 storage 5 °C = NS,T_5) and at (20 ± 2) °C (Na_2SO_4 storage 20 °C = NS,T_{20}).
- For the reference storage (CH), 3 flat prisms with measuring stud and 3 flat prisms without measuring stud will be stored standing on edge, standing on gratings in a saturated $Ca(OH)_2$-solution at (5 ± 2) °C (reference storage 5 °C = CH,T_5) and at (20 ± 2) °C (reference storage 20 °C = CH,T_{20}).

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

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

The Na_2SO_4 solution shall be replaced every 14 days with a new Na_2SO_4 solution, temperature-controlled at (5 ± 2) °C respectively (20 ± 2) °C.

After a storage period of 90 days, the Na_2SO_4 solution shall be replaced monthly with a new Na_2SO_4 solution tempered at (5 ± 2) °C respectively (20 ± 2) °C until the end of the test.

The saturated $Ca(OH)_2$-solution shall be checked every 14 days for its saturation. If needed, the solution shall be concentrated.

A.2.5 Initial measurement procedure

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

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

The flat prisms shall be weighed on a balance to an accuracy of 0.01 g (w_0).

The length of the flat prisms (with measuring studs) (l_0) will be measured on a dial gauge with an accuracy of 0.001 mm.

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

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

A.2.6 Further measurement procedure

After 13, 26, 39, 52, 65, 78, 91, and 104 weeks of storage (t_i) in the respective test solutions (NS and CH) and storage temperature (T = 5 °C and 20 °C), the test specimens shall be removed from the containers to determine the specimen length ($l_{NS,(ti,T)}$ and $l_{CH,(ti,T)}$), the mass ($w_{ti,T}$) and the longitudinal resonance frequency ($F_{L,NS(ti,T)}$ and $F_{L,CH(ti,T)}$) for the determination of the dynamic modulus of elasticity ($E_{d,NS(ti,T)}$ and $E_{d,CH(ti,T)}$).

For the tests, the test specimens shall be dried with a damp cloth after removal from the test solution at a room temperature of (20 ± 2) °C and a relative air humidity of (65 ± 5) %.

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

The flat prisms shall be weighed on a balance to an accuracy of 0.01 g ($w_{NS,(ti,T)}$ and $w_{CH,(ti,T)}$).

The length of the flat prisms (with measuring studs) ($l_{NS,(ti,T)}$ and $l_{CH,(ti,T)}$) will be measured on a dial gauge with an accuracy of 0.001 mm.

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

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

A.2.7 Analysis

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

$$\Delta l_{NS(ti,T)} = (l_{NS(ti,T)} - l_0) \times 1000/160 \text{ [mm/m]}$$

$$\Delta l_{CH(ti,T)}) = (l_{CH(ti,T)} - l_0) \times 1000/160 \text{ [mm/m]}$$

where:

- l_0 is the length of the flat prisms [mm] after pre-storage (t = 0)
- $l_{NS(ti,T)}$ is the length of the flat prisms [mm] at storage time (t_i) in Na_2SO_4-solution at a storage temperature of (5 ± 2) °C and (20 ± 2) °C (T)
- $l_{CH(t,T)}$ is the length of the flat prisms (mm) at storage time (t_i) in $Ca(OH)_2$-solution at a storage temperature of (5 ± 2) °C and (20 ± 2) °C (T)
- t_i is the storage time 14, 28, 56, 91, and 182 days

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

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

ANNEX B BASICITY OF THE PORE WATER SOLUTION IN THE BLENDED CEMENT MIXED WITH AGGREGATES

B.1 Principle of the test

The test consists in placing a porous material in a hydraulic press and squeezing it until the pore fluid is expelled from the specimen. The pore solution is formed during the reaction of the blended cement with the water.

B.2 Specimen preparation

Squeezing test shall be performed on one specimen in accordance with

Table 2.2.10.1 composition. Extraction tests shall be carried out after 90 days of endogenous curing at a temperature of 20 ± 2 °C.

At 90 days of age, the specimens shall be crushed into fragments of 3–5 cm and the extraction shall be performed using about 280 g of crushed material.

B.3 Squeeze-out-procedure

The squeeze-out of the pore solution as far as hardened blended cement specimens were concerned, shall be carried out using the high-pressure press technique on the pre-set examination dates (see Figure B.3.1).

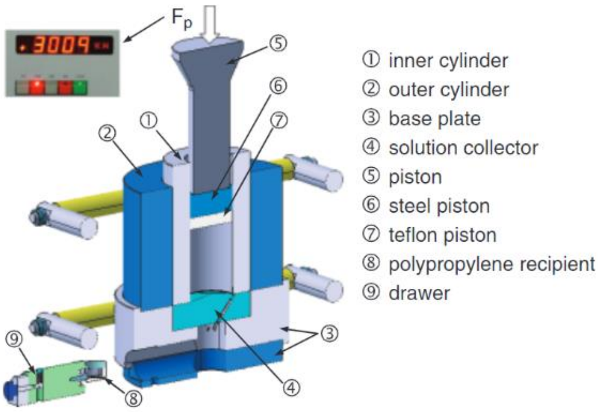

Figure B.3.1 Extraction device (Cyr et al. 2008)

Before each test, the inner chamber of the device shall be cleaned and covered with a thin layer of sprayed Teflon.

This coating reduces the friction between the specimen fragments and the inner cell wall and thus facilitated the transfer of the applied pressure to every point of the specimen and the removal of the squeezed specimen after the extraction.

After a curing of 90 days in autogenous conditions and crushing, the hardened blended cement specimen shall be inserted into the cylindrical opening of the press die. Then, the press die shall be completed and arranged centrically under the load plates of a compressive strength testing machine.

One extraction shall be carried out on a 3000 kN compression testing machine or equivalent, allowing to exert a pressure of 1000 MPa[12]. A loading rate of 1 MPa/s shall be used which leads to an extraction time of 1000 s. Although slower rate can lead to better extraction efficiency, by giving the pore solution time to exit the specimen, it is not advised to increase the duration in order to avoid the carbonation of the solution. The pore solution shall be collected with a polypropylene recipient.

B.4 Analysis of the pore solution

The pH of the pore solution shall be determined as soon as possible after collection using a standard pH-meter.

12 Cyr, Rivard et al., *High-Pressure Device for Fluid Extraction from Porous Materials: Application to Cement-Based Materials*, in J. Am. Ceram. Soc., 91 [8] 2653–2658 (2008)

ANNEX C ALKALI-SILICA REACTION[13]

C.1 Principle

Test prisms shall be prepared according to Clause C.2.2 and stored in hot (60 ± 2) °C, humid conditions for at least 20 weeks to promote any alkali-aggregate reaction. Measurements shall be made at periodic intervals to determine whether any expansion has occurred.

C.2 Description of the test method

C.2.1 Mix compositions and preparation

The blended cement shall be mixed with water and aggregates. Mix B (see Table C.2.1.1) shall be used[14].

Table C.2.1.1 Composition of mix for alkali-silica reaction

Mix identification	Composition per m^3
Mix B[(a)]	Blended cement content = 350 kg NaOH = adjusted so the equivalent alkali content of the mix is equal to: 5.5 kg Siliceous limestone or flint aggregate (0/4 mm) reactive[(b)] sand = 920 kg[(c)] Limestone aggregate (4/10 mm) non-reactive = 423 kg Limestone aggregate (10/20 mm) non-reactive = 684 kg Aggregates in accordance with EN 12620 and complying with EN 480-1 requirements shall be used. W_{Eff}/B max= 0.34 Water reducing admixture (if necessary) to achieve a minimum consistence class S3[(d)].

(a) The Mix B is defined on the assumption that the density of the blended cement is 2850 kg/m^3, the density of siliceous limestone aggregate is 2660 kg/m^3 and limestone aggregate is 2720 kg/m^3.

(b) An aggregate is considered reactive if the characteristic expansion value of the test prisms is higher than 0.02 % at 5 months (20 weeks) at T = (60 ± 2) °C, according to assessment method given in Clause C.3.

(c) The 920 kg are defined for a density of 2660 kg/m^3 meaning 346 L. With a different density of the material, the mass shall be adapted to obtain the same volume.

(d) Consistence class in accordance with EN 206, Clause 4.2.1, Table 3; evaluation in accordance with EN 12350-2.

The aggregate fractions shall be combined in mass proportions calculated on a saturated surface dry basis according to Table C.2.1.2 given below, which gives the recommended aggregate grading curve range to achieve a matrix suited for production of workable and stable mix. In order to meet these requirements, it is necessary to know the particle size distribution curve of each aggregate.

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13 This annex presents the complete assessment method for assessing the product's performance. For transparency purpose, it is specified that this annex is adapted from the RILEM Recommended test method AAR-4.1 – Detection of potential alkali-reactivity – 60 °C test method for aggregate combinations using concrete prisms. The method covers the measurement of expansion produced by alkali-aggregate reaction of concrete prisms stored in an environment which accelerates the reaction, since there is currently no existing European standard available on the subject

14 Due to its composition, the density and water demand of the blended cement (according to Manufacturer's utilisation instruction manual) may be different from those assumed in the composition of Mix B, which shall therefore be adapted to maintain 1 m^3 of mix with a minimum S3-class consistency. If the density of blended cement is different, maintaining 350 kg of blended cement per m^3 will result in a different paste volume. Similarly, if the water demand of the blended cement is different, maintaining an S3-class consistency by adjusting water-cement ratio will result in a different paste volume. In all cases, to maintain 1 m^3 of mix, the volume of paste shall be completed by the volume of aggregates. Depending on the density of the aggregates, the mass of each aggregate class shall be adjusted while keeping the relative proportion of each class constant.

Table C.2.1.2 Recommended aggregate grading (the range is selected to accommodate both crushed and uncrushed aggregate)

Aperture size [mm]	Percentage by mass passing the test-sieve
22.4	100
16.0	75-95
8.0	45-70
4.0	35-55
2.0	25-45
1.0	20-35
0.5	10-25
0.25	4-12
0.125	1-8

C.2.2 Specimens

Three steel moulds suitable for casting prisms of lengths (280 ± 10) mm and a square cross section of edge (75 ± 5) mm shall be used for the prism production. The moulds have the facility for casting stainless steel reference studs into the mid-points of the end faces of the prisms.

At least 3 specimens shall be manufactured for the determination of the length. The mix shall be poured and compacted in two layers.

The prisms shall be equipped with measuring studs made of corrosion-resistant material at the end faces.

After manufacture, the prisms shall be stored for (24 ± 2) hours covered with damp cloths at a temperature of (20 ± 2) °C.

C.2.3 Initial measurement procedure

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

Immediately weigh the prisms to the nearest 1 g (W_0) and measure the initial length (l_0) of each prism to the nearest 1 mm using a steel rule.

Clean the reference studs and take an initial reading on the comparator (C_0) using an Invar rod to calibrate the length of the measuring apparatus. For each measurement, keep the Invar rod and the prism in the same position (top and bottom in position, the same rod surface and same prism face towards the operator). Ensure the prism is properly located in the measuring apparatus before making any readings. Initial measurements shall be made at a temperature of (20 ± 2) °C.

These and all subsequent measurements shall be made at a temperature of (20 ± 2) °C.

Note: Demould and measure the prisms in sets of three. Do not demould all the prisms and attempt to measure consecutively as this will result in too much drying, which could affect the expansion behaviour.

Afterwards, the prisms shall be immersed for (30 ± 5) minutes into (20 ± 2) °C water.

The surface water shall be then removed with a damp sponge.

Clean the reference studs and make second measurements of weight (W_0') and using the comparator (C_0'), as a check. W_0' shall be slightly higher than W_0 and C_0' shall be equal to C_0 (with deviation lower than 3 µm) (meaning that the weight of the prisms shall increase slightly and its length shall remain similar).

After the second measurement (control measurement), the 3 prisms shall be stored in a sealed container (Figure C.2.3.1), which meets the following requirements:

- Interior dimension: e.g., Length × Width × Height = 280 mm × 130 mm × 400 mm
- Water-level: (35 ± 5) mm
- Height of the support grid for the specimens: 50±5 mm

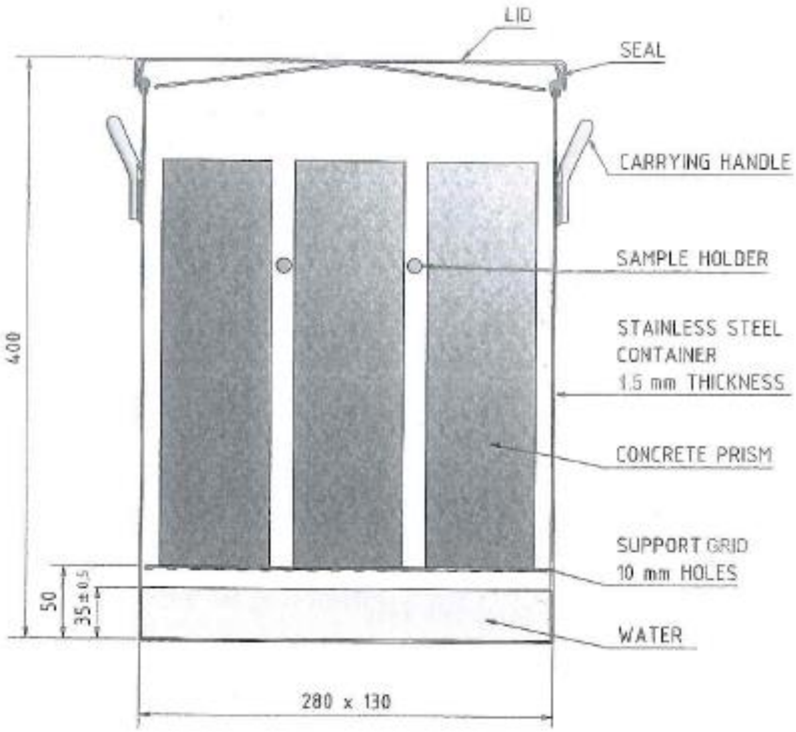

Figure C.2.3.1 Principle of the sealable container for storing prisms (dimension in mm)

Figure C.2.3.2 Sealable container for storing prisms

The containers (Figure C.2.3.2) shall be placed in a test cabinet (ASR reactor; see Figure C.2.3.3) with an air temperature of (60 ± 2) °C and a relative humidity of at least 98 %. To meet these requirements, test cabinets with the following characteristic values have been used so far:

- Interior dimension: e.g., Length × Width × Height = 1500 mm × 1100 mm × 950 mm
- Water-level of the heated water bath: (190 ± 10) mm
- Height of the support grid for the specimens: 280±10 mm
- Temperature measurement: in the airspace of the test cabinet

Figure C.2.3.3 Test cabinet (ASR reactor) with an air temperature of (60 ± 2) °C and a relative humidity of at least 98 %

Place the prism in containers with (35 ± 5) mm of water at the bottom. Each sealable container holds a maximum of either three prisms, see Figure C.2.3.3. It is important that a full set of specimens (3) is in the container. If fewer test specimens are needed the number shall be made with "dummy" specimens. Put all the sealed containers in the (60 ± 2) °C reactor and ensure the reactor contains an appropriate level of water.

The measuring length of the measuring device (length comparator) shall be greater than (280 ± 10) mm. The device shall be manufactured in such a way that the measuring studs matches the measuring marks in the prism and that the measuring gauge is rigid in vertical direction.

The graduation of the gauge shall not be greater than 0.002 mm and the error throughout the range of transvers shall not be more than 0.005 mm (reference temperature: 20 °C).

An Invar rod suitable for the measuring studs shall be used as the calibration rod.

C.2.4 Procedure for length and weight measurements

Remove the sealed containers from the reactor and ensure the cover is securely in place. DO NOT OPEN the containers. Store the containers at (20 ± 2) °C for (24 ± 2) hours, to cool them, in a high relative humidity chamber if possible.

Make an initial reading on the comparator using the Invar rod to calibrate the length of the measurement apparatus.

Follow the steps 1 to 11, to measure the prisms in each container

Each prism measurement shall take no more than 3 min to avoid excessive drying. Follow the steps 1 - 5, to measure the prisms in each container. Always measure the prisms in the same sequence as in the reference measurement.

1. Take the first prism from the container and close the container cover immediately;
2. Clean the reference studs carefully and place the prism in the apparatus.

3. Measure the length of prism i using the comparator ($C_{t,i}$ where t = time in days). For each measurement, keep the prism in the same position (top and bottom in position, the same prism face toward the operator, arrow pointing in the same direction). Ensure the prism is well located in the measuring apparatus before making any readings.
4. Remove any excess of moisture and weigh the prism i ($W_{t,i}$ where t = time in days) to nearest 1 g.
5. Examine the prism and note and report any cracking, gel exudations, warping or other features.
6. Return the prism to its container.
7. Remove the next prism from the container and put back into the container cover immediately.
8. Repeat step 2-6 also for the second and third prism from the container.
9. Once all prisms from one container have been measured, check the reading of the Invar rod. If the difference is more than 0.003 mm from the first measurement, re-measure the three prisms for this container again, following steps 1 through 5.
10. Check the water level in the container is (35 ± 5) mm, adjust water content if necessary and close the container cover.
11. Restore the container in the reactor.

Repeat steps 1 – 11 for all containers. Check the water level in the reactor and add water if necessary. Replace all the containers into the reactor.

C.2.5 Measurement timetable

Measure the prisms ($C_{t,i}$ and $W_{t,i}$) according to the detailed procedure at 28, 56, 84, 112, and 140 days after the initial measurements. Do not remove the prisms from the container between the measurements. Do not make intermediate measurements, especially if applying pre-cooling, to avoid increasing the alkali leaching and for preventing moisture loss.

C.2.6 Calculation

For each period of measurement, calculate the change in length and weight for each prism from the difference between the reference comparator or weight measurement ($C_{0,i}$; $W_{0,i}$) and the comparator or weight measurement after that period ($C_{t,i}$; $W_{t,i}$). Calculate each length change as a percentage of the initial length (l_i) of the corresponding prism to the nearest 0.001 % and the weight change as a percentage of the reference weight (W_0) of the corresponding prism to the nearest 0.01 %.

For example, at 140 days the percentage length change $\Delta E_{t,i}$ [%] of a prism (i being the identification number of the core) $\Delta E_{140,i}$ [%] as follows:

$$\Delta \mathrm{E}_{140,} = \frac{\mathrm{C}_{140,\mathrm{i}} - \mathrm{C}_{0,\mathrm{i}}}{l_i} \times 100$$

where:

- $C_{140,i}$ is the comparator measurement at 140 days age of the prism i;
- $C_{0,i}$ is the reference comparator measurement of the prism i;
- l_i is the initial length [mm] of prism i.

The corresponding percentage weight change $\Delta W_{t,i}$ [%] of a prism at 140 days shall be expressed as $\Delta W_{140,i}$ as follows:

$$\Delta \mathrm{W}_{140,} = \frac{\mathrm{W}_{140,\mathrm{i}} - \mathrm{W}_{0,\mathrm{i}}}{\mathrm{W}_{0,\mathrm{i}}} \times 100$$

where:

- $W_{140,i}$ is the weight measurement of prism i, at age 140 days;
- $W_{0,i}$ is the reference weight of the prism i.

For each measurement age, also calculate the mean length change of the three prisms to the nearest 0.001 % and the mean weight change to the nearest 0.01 %.

For example, at 140 days the average percentage length change mE_{140} of the three test prisms shall be given by:

$$mE_{140} = \frac{\Delta E_{140,1} + \Delta E_{140,2} + \Delta E_{140,3}}{3}$$

C.3 Determination of reactivity of sand

To determine the reactivity of sand, it shall be assessed according to Clause C.2 with the following deviation:

- Instead of Mix B, Mix C shall be used (see Table below).

Table C.3.1 Composition of Mix C

Mix identification	Composition per m^3
Mix C	CEM I = 350 kg NaOH = adjusted so the equivalent alkali content of the mix is equal to: 5.5 kg Siliceous limestone or flint aggregate (0/4 mm) sand = 850 kg[(a)] Limestone aggregate (4/10 mm) non-reactive = 390 kg Limestone aggregate (10/20 mm) non-reactive = 630 kg Aggregates in accordance with EN 12620 and complying with EN 480-1 requirements shall be used. W_{Eff}/C max= 0.5 Water reducing admixture (if necessary) to achieve a minimum consistence class S3[(b)].

(a) The 850 kg are defined for a density of 2660 kg/m^3 meaning 320 L. With a different density of the material, the mass shall be adapted to obtain the same volume.

(b) Consistence class in accordance with EN 206, Clause 4.2.1, Table 3; evaluation in accordance with EN 12350-2.