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Framework for a specification on the avoidance of a damaging Alkali-Silica Reaction (ASR) in concrete

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Framework for a specification on the avoidance of a damaging Alkali-Silica Reaction (ASR) in concrete

Cadre d'une spécification destinée à prévenir les dégradations causées au béton par l'alcali-réaction

Anwendung von Qualitätsregelkarten bei der Herstellung von Beton

This Technical Report was approved by CEN on 14 February 2012. It has been drawn up by the Technical Committee CEN/TC 104.

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Foreword

This document (CEN/TR 16349:2012) has been prepared by Technical Committee CEN/TC 104 “Concrete and related products”, the secretariat of which is held by DIN.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CEN [and/or CENELEC] shall not be held responsible for identifying any or all such patent rights.

This Technical Report is partly based on the recommendation of RILEM TC ACS (Part 1 of AAR-7) [6].

Introduction

This Technical Report has been prepared by the Joint Working Group (JWG) on Alkali-Silica Reaction (ASR) that was set up by the chairmen of CEN/TC 51, CEN/TC 104 and CEN/TC 154 and composed of representatives from CEN/TC 51, CEN/TC 104, CEN/TC 154 and RILEM TC ACS.

The following is a list of the members of the JWG on ASR:

Name	Represents
Michel Delort	CEN/TC 51
Christer Ljungkrantz	CEN/TC 51
Tom Harrison	CEN/TC 104
Christoph Müller	CEN/TC 104
Philip Nixon (until 2009)	CEN/TC 154
Robert Gossling (from 2010)	CEN/TC 154
Jean-Marc Vanbelle	CEN/TC 154
Terje F. Ronning	RILEM
Ingmar Borchers (VDZ)	Guest

In CEN member countries, ASR has been recognised as a problem in concrete structures since the 1970s.Consequently, a number of countries have established provisions to avoid a damaging ASR. These provisions are currently set out in national guidance documents and specifications.

Provisions vary in the different CEN member countries and depend on local experiences; some member countries have not yet found the need to set up specifications.

The JWG was established to review the situation and to see whether it is possible to go further in providing pragmatic and unified economic European specifications for the avoidance of a damaging ASR in concrete.

The JWG concluded that, unless there is any sound scientific explanation of a damaging ASR which can be used uniformly all over Europe, it is premature to have harmonised classes for alkali-reactivity of aggregates and provisions for avoiding a damaging ASR on a European level. Additionally, safety margins are determined at national level and are related to the reliability at which a damaging ASR will not occur. Nevertheless, a framework for the specification of the avoidance of a damaging ASR in concrete can be given.

1 Scope

This Technical Report gives guidance for avoiding a damaging Alkali-Silica Reaction (ASR) in concrete.

2 Alkali-Silica Reaction (ASR)

Alkali-Silica Reactions in concrete are a result of reaction between the alkaline pore solution in concrete and reactive mineral species (as reactive silica and silicates) in the aggregate. The reaction leads to the formation of a gel that can absorb water and exert an expansive force on the concrete. In certain conditions, these reactions can lead to damaging expansions and cracking in the concrete. For such damaging expansion to occur, all of the following conditions must be present simultaneously:

— a critical amount of reactive mineral species;

— a sufficiently high alkali hydroxide concentration in the pore solution;

— a sufficient supply of water.

Effective specifications to avoid damage from the reaction are based on ensuring that at least one of these conditions is absent.

NOTE Another type of reaction between reactive mineral species in the aggregates and the alkaline pore solution, which has been reported (e.g. from Canada and China), is the alkali-carbonate reaction. As alkali-carbonate reaction has not been recognised as a significant problem in Europe, it is not covered by this Technical Report.

3 Elements of specifications

In order to promote the sustainable use of locally available materials, it is important to tailor the precautions to the environment that the structure is exposed to as well as to local experience in building practice. Based on these principles, specifications for avoiding a damaging ASR in concrete are given within the following structure:

a) characterisation of the environment (environmental category):

   1) degree of saturation of the concrete with water;

   2) alkali supply;

   3) further aggravating factors.

b) undertaking recommendations for precautionary measures appropriate to concrete, depending on the environmental category.

4 Characterisation of environment

When all the necessary compositional factors are present, the likelihood and extent of damaging alkali-silica reaction is dependent on the environment. Three levels of categorisation of environment are therefore appropriate:

— E1: the concrete is essentially protected from extraneous moisture;

— E2: the concrete is exposed to extraneous moisture;

— E3: the concrete is exposed to extraneous moisture and additionally to aggravating factors, such as de-icing agents, freezing and thawing (or wetting and drying in a marine environment) or fluctuating loads.

More details on the factors affecting the environmental categorisation are given in Table 1.

Table 1 — Environmental categories

Environmental categories	Description	Exposure of the concrete [a,b,c]
E1	Dry environment protected from extraneous moisture	- Internal concrete within buildings in dry [a] service conditions
E2	Exposed to extraneous moisture [b]	- Internal concrete in buildings where humidity is high; e.g. laundries, tanks, swimming pools - Concrete exposed to moisture from the external atmosphere, to non-aggressive ground or immersed in plain water or permanently immersed in seawater [c].
E3	Exposed to extraneous moisture plus aggravating factors	- Concrete exposed to de-icing salts - Concrete exposed to wetting and drying by seawater [c] or to salt spray - Concrete exposed to freezing and thawing whilst wet - Concrete subjected to prolonged elevated temperatures whilst wet - Concrete roads subject to fluctuating loads

[a] A dry environment corresponds to an ambient average relative humidity condition lower than 75 % (normally only found inside buildings) and no exposure to external moisture sources.

[b] A risk of a damaging ASR may exist for concrete that is unlikely to dry significantly during its serviceable life, even in a dry environment. Corresponding concrete structural elements should be included in category E2 and their dimensions may be defined in national specifications.

[c] Concrete constantly immersed in seawater does not suffer a higher risk of ASR than a similar element exposed to humid air, buried in the ground, or immersed in plain water, because the alkali concentration of sea water is lower than the alkali concentration of the pore solution of most concretes.

5 Precautionary measures appropriate to concrete

5.1 General remarks

Depending on the environmental category, precautionary measures have to be applied. The type of measure, as well as the limits and levels in a measure itself, shall be defined on a national level because they depend on the national safety margin, the experiences of building practices, and the geology and climate.

Precautionary measures include:

a) no measures necessary;

b) use of a non-reactive aggregate combination;

c) limiting the alkalinity of the pore solution by:

   1) the use of cement with a low effective alkali content;

   2) the use of an adequate proportion of slag, fly ash, silica fume or other pozzolana (in cement or as an addition);

   3) conforming to a numerical limit on the effective alkali content of the concrete;

   4) verification of the suitability of a concrete mix in a performance test.

NOTE The appropriate precautionary measures for different environmental categories are found in the provisions valid in the place of use. Examples are the proportion of the fly ash/ground granulated blastfurnace slag (ggbs) that is necessary to avoid a damaging ASR, or the limit on the effective alkali content of the concrete. Such examples differ between CEN member countries and depend on both the reactivity of the aggregate combination and the national determined safety margin.

5.2 Use of cement with a low effective alkali content

In the case of low-alkali Portland cements (CEM I), an upper limit of 0,60 mass % Na_2O-equivalent is generally applied. The use of such low-alkali cements has been found to be effective in some regions in preventing ASR damage. This measure may not be effective in the case of concretes with unusually high cement contents, concretes with significant alkalis from constituents other than the cement, if there are significant sources of extraneous alkali (e.g. concrete roads), or if the passage of moisture concentrates the alkalis in certain parts of the structure.

Other cement types with low effective alkali content can be manufactured (for example cement types containing slag, fly ash or natural pozzolanas as a main constituent). The allowable alkali content depends on the percentage of slag, fly ash or natural pozzolanas, although there is no agreed value at European level.

5.3 Use of slag, fly ash, silica fume or other pozzolana (in cement or as an addition)

The use of slag, fly ash, silica fume or other pozzolana (in cement or as an addition) can be very effective in preventing ASR damage. Fly ashes conforming to EN 450-1, ground granulated blastfurnace slag (ggbs) conforming to EN 15167-1 and silica fume conforming to EN 13263-1 have been well-established as effective concrete additions. The effectiveness of cement types containing siliceous fly ash, natural pozzolanas or granulated blastfurnace slag conforming to EN 197-1 is also well-established. Both provide effective protection against ASR damage, provided a sufficient proportion (as a proportion of the total cementitious material) is used. The proportion necessary depends on the reactivity of the aggregate combination and the properties of the granulated blastfurnace slag/fly ash/silica fume/natural pozzolana. The requirements naturally differ between CEN member countries.

5.4 Limiting the effective alkali content of the concrete

The alkalinity of the pore solution is primarily dependent on the alkali content of the concrete mix. The effective application of limiting the effective alkali content of the concrete requires

- either the classification of all constituents used for a specific concrete mix with respect to their effective alkali content,
- or the quality assured declaration of the average alkali level of each constituent and a measure of its variability.

All constituents may contribute alkalis, but usually the majority of effective alkalis come from the Portland cement clinker.

When using, granulated blastfurnace slag, fly ash, silica fume or other pozzolana, the contributions to the effective alkali content of the concrete depend on the proportion used and their reactivity.

If concrete is exposed to de-icing salts, the contribution of the de-icing salts to the effective alkali content of the concrete shall be considered.

NOTE 1 CEN/TC 154 is tasked with developing and publishing a test method for measuring the releasable alkalis from aggregates.

NOTE 2 CEN/TC 51 is tasked with developing a procedure for determining the effective alkali content of cement and additions and a way of reporting this information to users.

NOTE 3 EN 206 cannot contain limits on the effective alkali content of concrete, as this depends on the classification of the reactivity of the aggregate combination and the national safety margin. However, in a future revision of EN 206, it is expected that a common method for calculating and reporting the effective alkali content of concrete will be included.

5.5 Verification of the suitability of a concrete mix in a performance test

Performance tests have been used in several CEN member countries for more than a decade. They are presently covered by national provisions. With the aim to propose for European standardisation a robust common procedure, RILEM technical Committee 219-ACS is tasked with reviewing and developing test methodologies for the reliable accelerated performance testing for susceptibility to alkali reactions of particular concrete mixes.

5.6 Use of a non-reactive aggregate combination

The alkali-silica reactivity of aggregates should be assessed in accordance with the test methods/provisions valid in the place of use. The RILEM recommended methods may be used in some cases to identify “non-reactive aggregate” combinations. The suitability of the test methods shall be proven under the local conditions in a CEN member country. An aggregate combination is considered non-reactive if it passes the test(s) criteria that shall be applied in the place of use.

6 Summary

Based on the principles given in this Technical Report, a specification for minimising the risk of a damaging ASR may include the parameters/elements given in Figure 1. The number of precautionary measures and the associated limiting values for a particular structural element should be given in the provisions valid in the place of use.

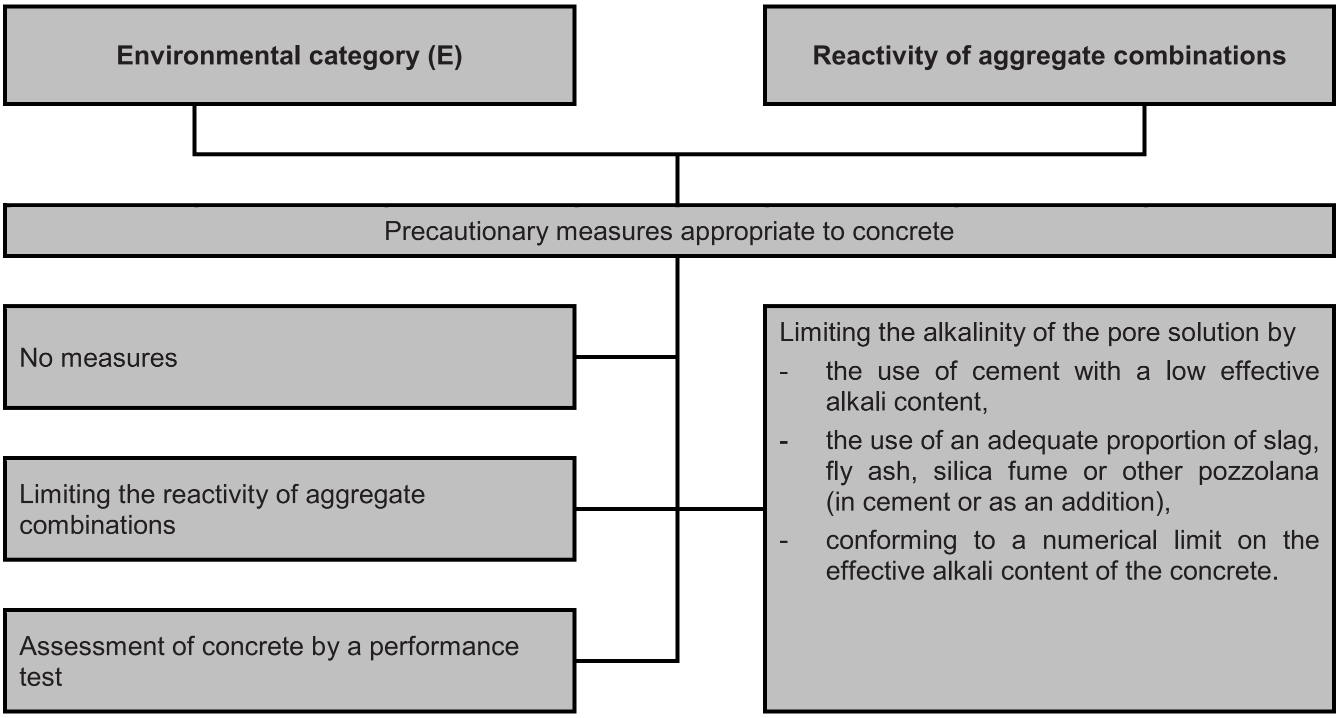

Figure 1 — Possible elements of a specification for minimising the risk of a damaging ASR

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

[2] prEN 206, *Concrete - Specification, performance, production and conformity*

[3] prEN 450-1, *Fly ash for concrete — Part 1: Definition, specifications and conformity criteria*

[4] EN 13263-1:2005+A1:2009, *Silica fume for concrete — Part 1: Definitions, requirements and conformity criteria*

[5] EN 15167-1, *Ground granulated blast furnace slag for use in concrete, mortar and grout — Part 1: Definitions, specifications and conformity criteria*

[6] RILEM TC ACS AAR-7.1: *Alkali Aggregate Reaction in Concrete Structures: International Specification to Minimise Damage from Alkali Reactions in Concrete: Part 1 Alkali-Silica Reaction* (Draft March 2008)

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