SLOVENSKI STANDARD
SIST-TP CEN/TR 16563:2013

01-december-2013

Postopkovna načela za ugotavljanje trajnosti

Principles of the equivalent durability procedure

Verfahrensgrundsätze zum Nachweis gleichwertiger Dauerhaftigkeit

Principes de la procédure de durabilité équivalente

Ta slovenski standard je istoveten z: CEN/TR 16563:2013

ICS:

91.100.30	Beton in betonski izdelki	Concrete and concrete products

SIST-TP CEN/TR 16563:2013 **en,fr,de**

TECHNICAL REPORT

RAPPORT TECHNIQUE

TECHNISCHER BERICHT

CEN/TR 16563

August 2013

ICS 91.100.30

English Version

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This Technical Report was approved by CEN on 22 June 2013. It has been drawn up by the Technical Committee CEN/TC 104.

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EUROPEAN COMMITTEE FOR STANDARDIZATION
COMITÉ EUROPÉEN DE NORMALISATION
EUROPÄISCHES KOMITEE FÜR NORMUNG

Management Centre: Avenue Marnix 17, B-1000 Brussels

Ref. No. CEN/TR 16563:2013: E

Contents

Page

Foreword

This document (CEN/TR 16563:2013) has been prepared by Technical Committee CEN/TC 104 “Concrete and related products”, the secretariat of which is held by DIN.

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Introduction

(1) The Equivalent Durability Procedure (EDP) is a scheme that builds on the traditional method of ensuring durable concrete by specifying established limiting values in terms of maximum w/c ratio, minimum cement content etc. Essentially, a reference value is determined and a candidate concrete can be confirmed as being of equivalent performance where testing and other appropriate assessments are made to demonstrate equivalent performance with this reference value or reference concrete. The reference value is determined based on concretes that satisfy fully the limiting value specification valid in the place of use and are representative of concretes that are successfully used in the local environment as providing a satisfactory service-life. To be considered a viable alternative, the proposed candidate concrete need to have a test performance that equals, or is better than, the reference value when tested by the same method and at the same age as used to establish the reference performance. Such a comparison leads to equivalent performance in the test at the age of testing. As the rate of improvement in resistance is not constant between concretes, the reference value will be appropriate for the constituents used in the candidate concrete.

(2) No relatively short-term laboratory test will give a precise quantitative indication of real performance of in-situ concrete. One reason for this is that concrete will continue to gain strength and resistance to the permeation of aggressive species in most natural environments, e.g. concrete will increase its resistance to the permeation of chloride ions with time, albeit at an ever decreasing rate. Such changes in performance over time, collectively called ‘ageing effects’, need to be taken into account when determining if the candidate concrete will provides an equivalent durability over the service-life.

NOTE With respect to durability, the changes can be positive or negative. For example, reaction with seawater may result in a surface layer that increasingly inhibits the penetration of chloride ions and hence improve durability. On the other hand, carbonation of concrete may release chlorides ions that were previously bound into the hydrate structure and, as these are then free to migrate towards any reinforcement, the durability may be reduced.

(3) Some CEN members have established national EDP type procedures which provide results that are likely to be reasonably indicative of in-situ performance or procedures whereby equivalent durability may be safely assumed for defined sets of materials. See Annex A to Annex H for some examples.

(4) This Technical Report provides guidance to National Standards Bodies who want to establish an EDP in their national provisions to EN 206.

1 Scope

This Technical Report sets out the principles of the equivalent durability procedure. It provides guidance on the selection of the reference value, production control, evaluation of conformity and the exchange of information between the parties.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

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

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

EN 206-1, *Concrete — Part 1: Specification, performance, production and conformity*

EN 450-1, *Fly ash for concrete — Part 1: Definition, specifications and conformity criteria*

EN 480-11, *Admixtures for concrete, mortar and grout — Test methods — Part 11: Determination of air void characteristics in hardened concrete*

EN 933-9, *Tests for the geometrical properties of aggregates — Part 9: Assessment of fines — Methylene blue test*

EN 1992-1-1, *Eurocode 2 — Design of concrete structures — Part 1-1: General rules, and rules for buildings*

EN 12350-1, *Testing fresh concrete — Part 1: Sampling*

EN 12390-2, *Testing hardened concrete — Part 2: Making and curing specimens for strength tests*

EN 12390-3, *Testing hardened concrete — Part 3: Compressive strength of test specimens*

EN 12390-8, *Testing hardened concrete — Part 8: Depth of penetration of water under pressure*

CEN/TS 12390-9, *Testing hardened concrete — Part 9: Freeze-thaw resistance — Scaling*

CEN/TS 12390-10, *Testing hardened concrete — Part 10: Determination of the relative carbonation resistance of concrete*

CEN/TS 12390-11, *Testing hardened concrete — Part 11: Determination of the chloride resistance of concrete, unidirectional diffusion*

EN 12620, *Aggregates for concrete*

EN 13263-1, *Silica fume for concrete — Part 1: Definitions, requirements and conformity criteria*

EN 13295, *Products and systems for the protection and repair of concrete structures — Test methods — Determination of resistance to carbonation*

EN 13369, *Common rules for precast concrete products*

EN 13396, *Products and systems for the protection and repair of concrete structures — Test methods — Measurement of chloride ion ingress*

EN 13670, *Execution of concrete structures*

EN 14216, *Cement — Composition, specifications and conformity criteria for very low heat special cements*

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

CEN/TR 15177, *Testing the freeze-thaw resistance of concrete — Internal structural damage*

ISO 5725-6, *Accuracy (trueness and precision) of measurement methods and results — Part 6: Use in practice of accuracy values*

ISO 16204, *Durability — Service life design of concrete structures*

BS 7979, *Specification for limestone fines for use with Portland cement*

BS 8500-1, *Concrete — Complementary British Standard to BS EN 206-1 — Part 1: Method of specifying and guidance for the specifier*

BS 8500-2, *Concrete — Complementary British Standard to BS EN 206-1 — Part 2: Specification for constituent materials and concrete*

DIN 1045-2, *Concrete, reinforced and prestressed concrete structures — Part 2: Concrete — Specification, properties, production and conformity — Application rules for DIN EN 206-1*

LNEC E 391, *Concrete. Determination of carbonation resistance* (In Portuguese)

LNEC E 392, *Concrete. Determination of the permeability to oxygen* (In Portuguese)

LNEC E 393, *Concrete. Determination of the absorption of water through capillarity* (In Portuguese)

LNEC E 463, *Concrete. Determination of diffusion coefficient of chlorides from non-steady state migration test* (In Portuguese)

NEN 8005, NEN, Nederlandse invulling van NEN-EN 206-1: *Beton — Deel 1: Specificatie, eigenschappen, vervaardiging en conformiteit* (Dutch supplement to NEN-EN 206-1)

NT BUILD 492, *Concrete, mortar and cement-based repair materials: chloride migration coefficient from non-steady-state migration experiments*

3 Terms and definitions

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

3.1
ageing effects
changes in a concrete resistance to aggressive species as the result of the progression of the hydration together with the time evolution of cement phase microstructure, its interaction with the penetration species and, in certain cases, of concrete surface changes due to its direct interaction with the external environment

Note 1 to entry: Example for interaction with the penetration species is: chloride binding.

Note 2 to entry: Example for direct interaction with external environment is: a skin effect when concrete is exposed to seawater.

3.2
candidate concrete
concrete comprising a closely defined set of constituents under investigation to determine the mix proportions that are likely to provide a durability performance equal to or greater than a reference value or reference concrete for the selected exposure class

3.3
equivalent durability – related test performance
procedure based on testing, by which a candidate concrete is shown to have equal or better performance than a reference value - when checked for the performance criteria linked to a selected exposure class

Note 1 to entry: The process includes the definition of the performance value, testing the candidate concrete with a performance test at a specified age, and comparing it with the appropriate reference value of performance or the performance of the reference concrete at the same age.

3.4
reference concrete
concrete where all the constituents and mix proportions are prescribed, conforming to the EN 206 provisions valid in the place of use and representative of the national/local experience in the defined exposure class.

3.5
reference value
value that the candidate concrete has to achieve or be better than and which is determined from either:

a) a previously established value where this has been established from any combination of testing or service-life modelling;

b) tests on the reference concrete;

c) a value selected from the range of values resulting from testing concretes that conform to the provisions valid in the place of use and is representative of the national/local experience in the defined exposure class

4 Principle

(1) The equivalent durability procedure (EDP) is a scheme for establishing conformity to EN 206 of concrete compositions that deviate from the limiting value criteria valid in the place of use. Durability testing to meet defined criteria is undertaken and this leads to a limiting value specification that is valid only for the constituents used in the candidate concrete. This procedure only applies to concrete compositions that comprise constituents (natural, manufactured or recycled) covered by European technical specifications referred to in EN 206 or provisions valid in the place of use.

(2) The procedure is applicable to any exposure class, but in practice it is limited to exposure classes where there are agreed standardized test methods (see 5.2). The application of the EDP is not appropriate for the X0 exposure class, as there are no environmental conditions that are aggressive to concrete or reinforcement.

(3) The EDP is to determine the equivalence of a candidate concrete used with the same minimum cover in the same exposure classes and intended working life as those appropriate for the reference value.

(4) The EDP includes at least three parts:

— Part 1: The setting of a reference value or the prescription of a reference concrete from which a reference value can be determined;

— Part 2: Initial testing and assessment of the candidate concrete to establish specific limiting values;

— Part 3: Continuous production control and conformity assessment to the determined limiting values.

(5) Part 1 requires for each exposure class, a reference value or a reference concrete to be selected.

(6) The Part 2 always has Stage 1 and in some cases, also a Stage 2.

Stage 1

(7) Candidate concretes are tested and compared with the reference value/concrete based on the same test methods at the same ages. Measurement uncertainty has to be taken into account. Equivalent durability at the age of testing is achieved when the candidate concrete has a measured value equal to or less than, i.e. better performance than, the reference value or the measured value of the appropriate reference concrete after taking account of measurement uncertainty.

NOTE With the carbonation test, chloride diffusion test and the freeze-thaw test, the lower the measured value the better is the performance.

Stage 2

(8) Assessing the relative performance of a concrete at a young age may not adequately reflect relative performance over the full life of the structure due to ageing effects. If the reference value or reference concrete has a similar cement/addition type to the candidate concrete, Stage 2 is satisfied and the concrete may be assumed to provide a similar durability over the life cycle. In other cases further action is required to show a similar performance over the life cycle before the claim of an equivalent durability performance may be made (see 7.1.3).

(9) The EDP leads to a set of limiting values that are specific to the constituents used in the initial testing.

(10) Part 3 of the procedure involves demonstrating conformity to these limiting values plus some form of check that the constituents have not changed significantly is used to establish conformity of the production concrete.

(11) To generate confidence in the system, it is strongly recommended that the initial testing and periodic re-validation are undertaken by a party that is independent of the concrete producer and that testing is undertaken by laboratories that are accredited, or approved on a national basis, for the test procedure.

5 Selection of test methods

5.1 Requirements for a test method

The test method is required to:

- be relevant to the deterioration mechanism for which performance is being compared;
- have an established and documented relationship with performance in practice in the defined exposure class;
- be of a known and adequate precision;
- be sensitive to variations in concrete composition and mix proportions.

5.2 Guidance on the selection of test methods

(1) Where test procedures valid in the place of use are applied for the assessment of new constituents and concretes it is appropriate to use such tests for the equivalent durability procedure. The test method applied should have known reproducibility and repeatability standard deviations. Most European performance-related durability test methods for concrete that are published have the status of Technical Specifications, as the test precision had not been established. When precision data are established, the tests will be upgraded to full European standards. Any national test method should be used in parallel with the European test procedure, so that experience with the European tests is gained and in the longer term Europe is able to adopt common test procedures.

(2) The performance-related test methods for concrete listed in Table 1 have been standardized and published at the European level.

(3) Some, but not all, test methods define the age of concrete at the start of the test. The age of the concrete at the start of the test will have an influence on the test result and it should not be presumed that a suite of concretes tested at one age will have the same ranking when tested at a different age.

Table 1 — Performance-related test methods that are, or are being, standardized at the European level [a]

CEN/TS 12390-9	Testing hardened concrete — Part 9: Freeze-thaw resistance — Scaling
CEN/TS 12390-10	Testing hardened concrete — Part 10: Determination of the relative carbonation resistance of concrete
CEN/TS 12390-11	Testing hardened concrete — Part 11: Determination of the chloride resistance of concrete, unidirectional diffusion
CEN/TR 15177	Testing the freeze-thaw resistance of concrete — Internal structural damage

[a] There are no exposure classes in EN 206 for abrasion, but they exist in other European and national standards and there are associated test methods.

6 Determination of the reference value

6.1 Requirements for a reference value

(1) Reference values may be established by:

— Selecting reference values from previously established values where these values have been determined from any combination of testing or service-life modelling. One approach is testing a range of concretes that fully satisfy the provisions valid in the place of use and are representative of national/local experience and then selecting one or more representative values. If more than one representative values are selected, each value should be associated with a particular type or types of cement or cement: addition ratio.

— Defining reference concretes and then testing them to determine reference values. The candidate concrete is then assessed using the same test methods as used to establish the reference values at the same test ages.

(2) Much of what is written in this Technical Report would also apply to a reference value determined from service-life design. However, for example, the diffusion coefficient required for the structure needs to be converted into a value from test specimens tested by a specified method at a specified age. A minimum requirement for ageing due to hydration would also have to be specified and how it is to be assessed, or the cement/addition type(s) permitted in the candidate concrete defined.

(3) When setting a reference value, it is simpler to take into account measurement uncertainty and require the measured value of the candidate concrete to achieve or be better than the reference performance, i.e. the numerical values are directly compared. If such an approach is followed, the minimum number of test samples for the candidate concrete will have to be specified as the uncertainty of measurement depends upon the number of test results.

(4) Where reference values are being specified, the following information has to be provided:

— the relevant exposure class;

— the limit value of the reference performance;

— the cement/addition type(s) and ratio associated with the reference value;

— the test method to be used on the candidate concrete;

— the age of testing of the candidate concrete, if not defined in the test standard;

— whether the limit value includes or does not include an allowance for measurement uncertainty;

— if measurement uncertainty is included, the minimum number of tests on the candidate concrete.

6.2 Requirements for a reference concrete

(1) A reference concrete is a prescribed concrete that satisfies all of the following conditions:

— it is a concrete conforming to EN 206 and conforming to the provisions valid in the place of use for the defined exposure class;

— its constituents meet the requirements of EN 206 and/or the provisions valid in the place of use for the defined exposure class;

— it is a concrete representative of the national/local experience in the defined exposure class.

Where compressive strength is part of the durability provisions valid in the place of use, the proportions of the reference concrete should be at least those needed to achieve the average strength of (f_{ck} + 1,64σ), where f_{ck} is the characteristic compressive strength of the concrete and σ is the estimate of the standard deviation of the population.

(2) To ensure a consistent concrete, the reference concrete needs to be fully prescribed and in addition to the specification requirements given in EN 206, this shall include the prescription of:

— type, source and content of the cement/addition;

— cement strength class;

— aggregate types and sources (e.g. Thames/Seine/Rhine/Tiber/Tagus Valley gravel);

— grading, shape and content of aggregates;

— admixture type, source and content.

(3) Due to potential differences in performance between different sources of the same type of cement, addition, aggregate or admixture the source of each constituent is an essential part of the prescription.

(4) A different reference concrete(s) should be selected for each of the XC, XD, XF and XS exposure sub-classes, e.g. XD1, XD2 and XD3, based on what is representative from those in current use. ‘Representative’ does not mean just conforming to the specified limiting values, e.g. the specified maximum w/c ratio, but a concrete that has a history of satisfactory use in practice. Limiting value specifications usually permit a range of constituent materials and when they are used at the same limiting values will generally not give a consistent performance, just a range of performances that are all deemed to satisfy. The reference concrete may be selected from the range of available representative concretes, but where the information is available it is recommended to select one that is in the mid-range of performance. For example it is known that at a given w/c ratio, CEM I concretes give the lower carbonation depths and cements with high levels of non-clinker materials give high levels of carbonation. Consequently, a CEMII/B concrete, where the clinker level is in the mid range at 65 % to 79 % clinker, would give a performance in the mid-range and may be considered an appropriate choice of reference concrete. Alternatively, and to avoid the complications of a Stage 2 assessment, a range of reference concretes based on different cement/addition types are specified. The candidate concrete is tested against the reference concrete with the same or similar cement type, as in the Dutch system, see Annex D.

(5) The concept of ‘representativeness’ applies also to the constituent materials used to produce the concrete.

(6) Care should be taken to ensure a representative concrete is selected as the reference concrete. It may be interpreted that a concrete at the limiting values would represent less than 5 % of concrete exposed to the environment. From this starting point it may be incorrectly assumed that a concrete at the limits of acceptability ((maximum w/c ratio + 0,02), (minimum cement content – 10 kg) and a compressive strength from either structural or durability requirements of (f_{ck} – 4)) will produce a concrete that represents the established good performance. In reality the established good performance is based on concrete at the target