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Principles of the equivalent durability procedure

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National foreword

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Principles of the equivalent durability procedure

Principes de la procédure de durabilité équivalente

Verfahrensgrundsätze zum Nachweis gleichwertiger Dauerhaftigkeit

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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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.

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.

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.

<u>Stage 1</u>

(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.

<u>Stage 2</u>

(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

values with their normal distributions of performance. A more robust approach is to set a reference concrete that achieves a strength of (f_{ck} + 8) and a w/c ratio of the (maximum w/c ratio – 0,02) as this concrete will be representative of concrete of established suitability. Setting the reference concrete on this approach means that normal variations in the production concrete will not reduce the durability of the production concrete below an acceptable level.

(7) The reference concrete should have at least the minimum cement content required by the provisions valid in the place of use that relate to EN 206 or the European precast product standard (EN 13369). In some cases, the prescribed (target) cement content will be higher than the minimum value as more cement will be needed to satisfy the maximum w/c ratio requirement or the w/c ratio used to achieve the strength of the representative reference concrete.

(8) The majority of concrete produced in Europe contains at least one admixture. To reflect practice, it is suggested that the specification for the reference concrete includes an appropriate admixture. Where the local provisions require air entrainment for freeze-thaw resistance (XF exposure classes), the specification of the reference concrete needs to include a specific source of air-entraining admixture and a target air content with an appropriate tolerance.

(9) Due to the difficulties of specifying a reference concrete that will give a consistent performance, it is strongly recommended that testing of the reference (and candidate) concretes is undertaken under the same accredited or approved laboratory.

7 Determination of equivalent durability-related test performance

7.1 Requirements for determining the equivalent durability-related test performance

7.1.1 General

(1) Equivalent durability-related test performance is established by initial testing and it should be undertaken by a Body that is independent of the concrete producer. This initial testing comprising Stage 1 and Stage 2 is used to determine the mix proportions for production. The production conforming to the procedures described in Clause 9 is taken as proof that the concrete achieves the determined limiting values and by implication an equivalent durability performance.

NOTE Production control is used to ensure the consistency of this established performance.

(2) If in the initial testing for the selected exposure class, a candidate concrete gives results, including the margin to take account of the uncertainties in the assessment, equivalent to, or better than, those of the specified reference concrete or reference performance when submitted to one or more test methods that are specified by the competent Body, e.g. a National Standards Body, the candidate concrete is deemed to have an equivalent durability-related test performance. This initial testing is required to take account of test precision but not potential variability of constituent materials; changes in constituent materials are taken into account during the production control.

(3) For example, an assessment of equivalent test performance might require at least three test results each for the reference and candidate concretes. This may, for example, be at least three results from three batches for a single candidate concrete or at least one test result from three different mixes all made with the same set of constituents. One of the mixes would be designed to give the required performance, one mix a better performance and the other mix a lower performance. The mix proportions that give the equivalent test performance may then be interpolated from the three measured values. The equivalent test performance and the associated mix proportions should not be determined by extrapolation beyond the range of the test values.

(4) The initial testing shall lead to the identification of:

- the sources and types of all constituents (it may also include sources and types of constituents that are demonstrably similar);
- maximum w/c ratio;

— minimum cement content;

— addition: cement ratio, where additions are used;

— minimum fines content (all particles <125 μ m);

NOTE For durability purposes, i.e. the achievement of a closed structure, fines are defined as all particles lower than 125 μm. 'Fines' comprises the sum of the cement, addition, filler and the fractions of the aggregates less < 125μm in size.

— reference strength;

— if specified, the reference value for any other test procedure;

— limiting mix proportions for production.

(5) The reference strength is the compressive strength of the concrete (cylinder or cube depending upon what measure of strength is used in production control) associated with the durability test performance of the concrete. Changes from this value are used in the production control as an indicator of changes in the performance of the constituents or the functioning of the plant, which could lead to an adverse change in durability.

7.1.2 Stage 1 assessment

(1) There are various methods for dealing with the uncertainty of measurement including:

— using the known test precision, see ISO 5725-6;

— other statistical methods such as the t-test;

— applying a safe margin.

7.1.3 Stage 2 assessment

(1) The objective of the Stage 2 assessment is to evaluate the durability performances of a candidate concrete that does not have the same rate of performance development as the reference concrete.

NOTE 1 If the cement type or (cement + addition type) is the same or similar for the reference and candidate concrete, no Stage 2 assessment is required.

NOTE 2 At the European level quantifiable provisions for a Stage 2 assessment cannot be given at this stage of the knowledge.

NOTE 3 For chloride resistance, one approach would be to test at two ages with the second age being at least one year after casting. For carbonation resistance one approach is to use the CEN/TS 12390-10 test at various ages up to 12 months or more and calculate 'k' and 'n' in the formula carbonation depth = k (time)^n.

(2) If the ageing factors of the reference and candidate concretes are known, modelling may be used to determine the equivalent durability; guidance is given in ISO 16204.

7.2 Conformity of requirements related to exposure classes

Conformity is based on conformity to EN 206 for:

— the limiting mix proportions for production determined by the initial testing (see 8.1);

— any other requirements placed on the production control, e.g. changes from the reference strength;

— other specified properties (e.g. compressive strength class, consistence).

7.3 Periodic validation or period of validity

(1) For short duration projects and where the concrete supply is shown to be consistent and of a high standard then a re-validation of performance should not be necessary. Under other conditions, or where the client deems it appropriate, a periodic re-validation of performance may be specified. The conditions for periodic re-validation should be established by the appropriate national body, e.g. National Standards Body.

(2) If a re-validation leads to new limiting values, these apply to the new production. The conformity of the concrete previously produced is not affected by any re-validation.

(3) An alternative approach and the one used for most technical approvals, is to put a time limit on the period of validity of the determined mix proportions. With technical approvals, this is typically in the range of three to five years.

7.4 Application at a national level

Application of this procedure at the national level requires a national application document (NAD) to define:

- for each exposure class, the reference concrete(s) or reference performance(s);
- for each exposure class, the appropriate test method or methods;
- the procedure for a Stage 2 assessment, where required;
- the minimum number of test results;
- calculation method or margin required for assessing equivalent test performance;
- conformity criteria for any test on the production that does not have criteria defined in EN 206;
- the period of validity for the determined limiting values or the maximum period between validations of performance;
- where appropriate, a statement of the form:

  The reference concrete/performance is selected to provide at least an average performance of those concretes currently accepted under the limiting value criteria. As EDP system is conservative, such an approach shall not be used to reject concretes that satisfy the current limiting value specification.

8 Production control

(1) The initial testing of the candidate concrete to confirm performance leads to a designed concrete with a minimum cement content, minimum addition content where used, a fixed ratio of cement to addition and a maximum water/(cement + addition) ratio and the reference strength for the specific set of constituents.

(2) It is recommended that the production control contains a check on whether the constituents are performing in the same way.

(3) As designed concretes require routine testing of strength, changes in compressive strength should be used as an indicator of change in the performance of the constituent materials/functioning of the plant.

(4) During initial testing, a reference compressive strength is determined and used to compare with subsequent results to help detect changes in the performance of the constituents. Any change in compressive strength should be investigated to determine the cause and whether it has a significant negative impact on durability.

NOTE Any changes to the cement plus addition content cannot change the cement: addition ratio.

If it can be shown and it is documented that the reduction in strength is due to changes in the cement strength or functioning of the concrete plant that has been corrected, the concrete shall be regarded as still providing the equivalent durability test performance and the w/c ratio need not be decreased except in the case where the specified compressive strength class is no longer being achieved.

(5) The produced concrete is required to conform to the requirements in EN 206-1 for designed concrete, e.g. batching tolerances and tolerances on consistence, and in addition, the sources and types of constituents shall not be changed until they have been proven by testing to be demonstrably similar.

(6) Durability-related performance tests may also be used to assess changes in the production by comparing the performance with the reference performance determined during the initial testing.

9 Evaluation and declaration of equivalent durability-related test performance

(1) All the results and analysis of the initial testing are to be recorded. Where the testing and analysis are not undertaken by a body that is independent of the concrete producer the records should be audited by the producer's certification body, or if this is not possible the audit should be carried by the second party. Testing should be undertaken by a laboratory accredited, or approved on a national basis, for the test procedure.

(2) The test report should include:

- the type and source of constituent materials used in the investigation;
- the properties of the constituent materials;
- the test results and analysis showing the relationship between test performance and mix proportions including the compressive strength and consistence;
- a statement of the mix proportions that give or exceed the equivalent performance;
- any observations about the likely performance in practice of the candidate concrete, e.g. over-cohesive.

(3) Before use, the producer is required to consider any observations about the likely performance and document their actions. In the producer's quality manual there should be a formal procedure for checking and accepting the limiting values determined from initial testing.

(4) The assessment and verification of the constancy of production requires documentation of the sources and types of constituent materials and a confirmation that these have been covered by the initial testing. In addition the evaluation of conformity includes checking that the batched quantities meet the target values within the EN 206 tolerances on batching. It should be noted that with modern auto-graphic records batch weights may be verified for every load. Where durability-related tests are part of the assessment and verification of the constancy of production, the results of these tests have to be documented together with the verification of whether the constancy of production has been achieved.

10 Interface with users

(1) In the exchange of information between the producer and user prior to supply, the producer shall inform the user that they intend satisfying the defined exposure classes using the EDP defined in the provisions valid in the place of use.

(2) The user should check with the client's representative, if any, that they accept durability requirements being satisfied by an EDP procedure. In particular, the user may wish to confirm with the client's representative:

a) the reference value or reference concrete;

b) any limitation on types and sources of materials for the candidate concrete;

c) reference strength;

NOTE This is a target strength and not a characteristic strength.

d) assumptions made with respect to any stage 2 assessment;

e) the calculation method or margin used to assess equivalence;

f) where required time limit or frequency of any periodic re-validation.

(3) As with any offer, the user is free to accept or reject the offer.

(4) If the user as part of the concrete specification wants the performance of the concrete to be determined and supplied under the EDP, they should allow sufficient time for the testing to be completed prior to supply.

(5) In accordance with EN 206 the producer is responsible for the declarations on the delivery ticket and this does not change when the EDP is used to satisfy the specified exposure classes.

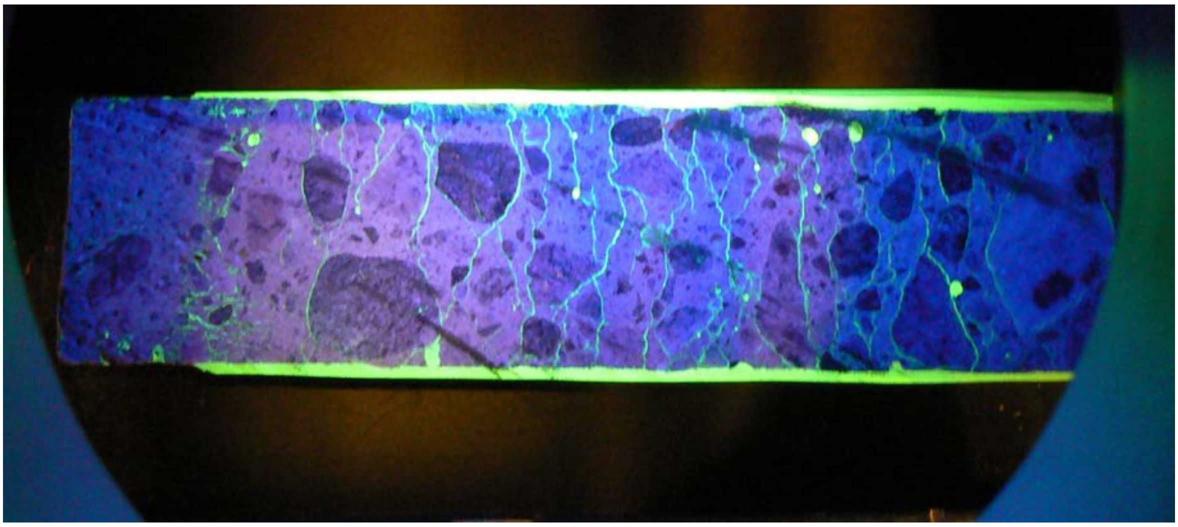
Annex A
(informative)

Finland —Testing of freeze-thaw resistance of a candidate concrete

A.1 Exposure classes XF1 and XF3

In exposure classes XF1 and XF3 the freeze-thaw attack takes place in the absence of de-icing salt and the failure mechanism is internal structure damage, see example in Figure A.1. In this case, cracks develop inside concrete which may not cause primarily scaling. In such a case, the suitable test method is CEN/TR 15177. This test indicates the development of cracks inside concrete by measuring reduction of the dynamic modulus of elasticity.

The ageing of the concrete does not change the freeze-thaw resistance of the concrete. Therefore, there is no need to take into account the ageing when comparing the freeze-thaw resistance of the candidate concrete with reference concrete.



The concrete sample is impregnated by resin and the fluorescence is visible in UV-light.

Figure A.1 — Cracks caused by freeze-thaw damage in balcony slab

Therefore, equivalent durability in terms of ‘Internal structural damage’ may be assessed by not having a greater reduction in the dynamic modulus when tested by the procedure described in CEN/TR 15177.

A.2 Exposure classes XF2 and XF4

In exposure classes XF2 and XF4 frost-thaw attack takes place in the presence of de-icing salts. In that case the suitable test method is CEN/TS 12390-9. The test is made with de-icing salt and the failure is seen as scaling on the surface of the sample, see example in Figure A.2.

The effect of the ageing of the test result depends on the composition of the binder used in concrete. The ageing effect is expressed by the formula:

$$k_{\text{binder}} = 1 - (0{,}020 \times sf + 0{,}008 \times bfs + 0{,}004 \times fa)$$

where

sf is the quantity of silica fume (% of binder)

bfs is the quantity of blast furnace slag (% of binder)

fa is the quantity of fly ash (% of binder)

Portland cement, CEMI, is regarded as not changing its resistance with time. When comparing the scaling of the candidate concrete with the scaling of the reference concrete, the influence of the ageing of the concrete on freeze-thaw resistance has to be taken into account:

$$\frac{m_{\text{ref}}}{k_{\text{binder,ref}}} = \frac{m_{\text{cand}}}{k_{\text{binder,cand}}}$$

Where

m_{ref} scaling of the reference concrete in the test (g/m^2)

m_{cand} scaling of the candidate concrete in the test (g/m^2)

Requirement for the scaling of the candidate concrete is then:

$$m_{\text{cand}} = \frac{k_{\text{binder,cand}}}{k_{\text{binder,ref}}} \times m_{\text{ref}}$$

Therefore equivalent durability corrected for the ageing effect may be ascertained where percentages of silica fume, ground granulated blastfurnace slag and fly ash are used.

The upper part of element was cast with non-air-entrained C25/30 concrete.

Figure A.2 — Precast concrete element exposed for 5 years to de-icing agent in a highway roadside in Finland

Annex B
(informative)

Germany

B.1 General

In Germany, the implementation of the EDP is under the mandate of national technical approvals (abZ) issued by Deutsches Institut für Bautechnik (DIBt). The approval procedure follows (individual) test plans issued for each individual case depending on the modification of DIN 1045-2 (NAD to EN 206-1) e.g.:

— application of cements where the use in some exposure classes was excluded due to the lack of experience in practice;

— application of new concrete constituents;

— concrete with a composition deviating from DIN 1045-2 (NAD to EN 206-1).

The evaluation of test results is under the mandate of the DIBt expert committees (SVA). The evaluation – especially of the durability test results – includes:

— assessment by limit values;

— assessment against DIBt data base (not published);

— comparison with a reference concrete.

The technical approvals also cover production control and third party inspection.

Following as examples the assessment procedure is given for:

— carbonation of concrete;

— resistance against chloride penetration;

— freeze-thaw resistance without de-icing agent;

— freeze-thaw and de-icing agent resistance.

The description of the test methods and the assessment are taken from a test plan for a technical approval procedure for cement. The procedure is used in the same or a comparable way for the application of new additions (e.g. GGBS) or concrete with a composition deviating from DIN 1045-2 (NAD to EN 206-1).

B.2 Carbonation of concrete

B.2.1 Method of verification

The carbonation depth of concrete made with “Product” is measured according to RILEM CPC 18 [1]. The resistance to carbonation has to be tested on prisms (40 mm × 40 mm × 160 mm) with aggregates according to EN 12620. The carbonation resistance is tested on concrete I, see Table B.1.

Table B.1 — Composition of concrete for the determination of carbonation depth

	Concrete mixtures for 3 specimens
concrete I	c = 450 g "Product (e.g. Combination: x % CEM I / y % limestone filler) g = 1350 g aggregates[a] w = 225 g water $\left(\frac{w}{c}\right) = 0{,}50$

[a] Aggregates according to EN 12620 with the following grading curve are used:

Size (mm)	0,25	0,5	1	2	4	8
Passing (% by mass)	8	21,5	36	46,5	67,5	100

The specimens are prepared according to EN 196-1. After demoulding half of the specimens are stored immersed in water (20 ± 2) °C until the age of 7 days and the other half until the age of 28 days. Afterwards the specimens are stored in climate 20 °C and 65 % relative humidity. Measurements of carbonation depth are performed after 14, 28, 56, 98 and 140 days as well as after 1, 2 and 5 years. The compressive strength is determined according to EN 196-1 after 35 days comprising 7 days in water followed by 28 days at 20 °C/65 % R or 28 days in water followed by 7 days in climate 20 °C/65 % RH and after 140 days in the climate of 20 °C/65 % RH (at the ages of 147 days (7 + 140) or 168 days (28 + 140)).

B.2.2 Method of assessing and judging

The carbonation depth and the carbonation speed of the concrete with “Product” is compared to a data base, see B.7. This data base is the basis of the evaluation for the granting of a national technical approval or a European technical approval. The carbonation depth and the carbonation speed of the concrete with the “Product” has to be located below or around the limit curve, see Figure B.1 to Figure B.4.

The carbonation speed is calculated by linear regression with:

$$d_c = d_0 + v_c \cdot \sqrt{t_c} \text{ expressed in mm / } \sqrt{d}$$

with

d_c = carbonation depth

t_c = duration of carbonation

v_c = carbonation speed

d_0 = specific parameter which depends on the storage and will be lower at a later start of testing the carbonation.

For the assessment of the carbonation resistance for the “Product” the carbonation depth is determined to a test age of 180 days. The carbonation is measured again on the same batch of concrete after 5 years to get data on the development of carbonation with time. The results are recorded and evaluated.

B.3 Resistance against chloride penetration

B.3.1 Method of verification

The resistance to chloride penetration of concrete with the “Product” and with Portland cement, CEM I conforming to EN 197-1 as reference is determined in accordance with NT BUILD 492. The resistance against chloride penetration is tested on concrete IIa and IIb, see Table B.2.

Table B.2 — Composition of concrete for the determination of the resistance against chloride penetration

	Composition per m^3 fresh concrete
concrete IIa	c = 320 kg "Product" (e.g. Combination: x % CEM I / y % limestone filler) g = ….. kg aggregates[a] $\frac{w}{c} = 0{,}50$
concrete IIb	c = 320 kg CEM I conforming to EN 197-1 g = ….. kg aggregates $\frac{w}{c} = 0{,}50$

a Aggregates according to EN 12620 with the following grading curve are used:

Size (mm)	0,25	0,5	1	2	4	8	16
Passing (% by mass)	6	14	22	32	46	68	100

B.3.2 Method of assessing and judging

For the test method given in B.8, the chloride migration coefficient of concrete (D_{mig}) with the “Product” is compared to the chloride migration coefficient of the reference concrete at ages of 35 and 97 days. The chloride migration coefficient of concrete (D_{mig}) with the “Product” at an age of 97 days are declared in accordance with the relevant category specified below according to the particular application or end use.

$$D_{mig,5}\text{:}\quad D_{mig} \leq 5 \cdot 10^{-12}\ m^2/s$$

$$D_{mig,10}\text{:}\quad D_{mig} \leq 10 \cdot 10^{-12}\ m^2/s$$

$$D_{mig,25}\text{:}\quad D_{mig} \leq 25 \cdot 10^{-12}\ m^2/s$$

$$D_{decl}\text{:}\quad D_{mig} > 25 \cdot 10^{-12}\ m^2/s$$

The above mentioned classes have been fixed by the DIBt expert committee (SVA) for the assessment of a new cement or addition for a national technical approval or a European technical approval. In Germany at least $D_{mig,25}$ has to be achieved.

B.4 Freeze-thaw resistance without de-icing agent

B.4.1 Method of verification

B.4.1.1 Method 1: Freeze-thaw resistance (Cube-Procedure) – FT_{cube}

The freeze-thaw resistance of concrete with the “Product” is determined according to CEN/TS 12390 9 (“cube procedure”) with 100 freeze-thaw-cycles. The freeze-thaw resistance (“cube procedure”) is tested on concrete III, see Table B.3.

Table B.3 — Composition of concrete for the determination of the freeze-thaw resistance without de-icing agent

	Composition per m³ fresh concrete
concrete III	c = 300 kg “Product” (e.g. Combination: x % CEM I / y % limestone filler) g = ….. kg aggregates $\frac{w}{c} = 0{,}60$

a Aggregates according to EN 12620 with the following grading curve are used:

Size (mm)	0,125	0,25	0,5	1	2	4	8	16	32
Passing (% by mass)	1,5*)	5	23	35	45	56	70	85	100

*) recommended value

Furthermore the compressive strength of concrete III is determined according to EN 12390-3 after 28 days. Concrete III is immersed in water after demoulding until the age of 7 days. Afterwards the specimens are stored in climate 20 °C/65 % RH.

B.4.1.2 Method 2: Freeze-thaw resistance (CF-Procedure) – FT_{CF}

The freeze-thaw resistance of concrete with and without ‘Product’ are determined according to CEN/TS 12390-9 (“CF-Procedure”). The internal structural damage is determined according to CEN/TR 15177.

The freeze-thaw resistance (“CF-Procedure”) is tested on concrete composition II a, see Table B.2. Furthermore the compressive strength of concrete IIa is determined according to EN 12390-3 after 28 days. The specimens are immersed in water after demoulding until the age of 7 days. Afterwards the specimens are stored in climate 20 °C/65 % RH. The relative dynamic modulus of elasticity (RDM) and scaling is measured after 0, 4, 10, 16, 22 and 28 freeze-thaw cycles.

B.4.2 Method of assessing and judging

B.4.2.1 Method 1: Freeze-thaw resistance (Cube-Procedure) – FT_{cube}

For the “cube procedure” according to CEN/TS 12390-9 scaling of concrete with the “Product” shall not exceed 10 % by mass after 100 freeze-thaw-cycles.

B.4.2.2 Method 2: Freeze-thaw resistance (CF-Procedure) – FT_{CF}

For the CF-test according to CEN/TS 12390-9 the relative dynamic modulus of elasticity has to be greater than 0,75 (75 %) after 28 freeze-thaw cycles (and scaling has to be less than 1 000 g/m² after 28 freeze-thaw cycles).

B.5 Freeze-thaw and de-icing salt resistance

B.5.1 Method of verification

The freeze-thaw and de-icing salt resistance of concrete with the “Product” is determined according to CEN/TS 12390-9 (“CDF-Procedure”). Furthermore the internal structural damage is also determined according to CEN/TR 15177. The freeze-thaw resistance with de-icing salt (“CDF-Procedure”) is tested on concrete composition IV, see Table B.4.

Table B.4 — Composition of concrete for the determination of the freeze-thaw resistance with de-icing agent

	Composition per m^3 fresh concrete
concrete IV	c = 320 kg “Product” (e.g. Combination: x % CEM I / y % limestone filler) g = ….. kg aggregates[a] Concrete with air entraining agent. (The air content of the fresh concrete has to be volume fraction of 4,5 ± 0,5 %.) $\frac{w}{c} = 0{,}50$

[a] Aggregates according to EN 12620 with the following grading curve are used:

Size [mm]	0,25	0,5	1	2	4	8	16
Passing [% by mass]	6	14	22	32	46	68	100

Furthermore, the compressive strength of concrete IV is determined according to EN 12390-3 after 28 days. The specimens are immersed in water after de-moulding until the age of 7 days. Afterwards the specimens are stored in climate 20 °C/65 % RH. The air void parameter is determined according to EN 480-11 on concrete IV. The relative dynamic modulus of elasticity (RDM) and scaling are measured after 0, 4, 6, 14, and 28 freeze-thaw cycles.

B.5.2 Method of assessing and judging

For the CDF-Test according to CEN/TS 12390-9 the scaling is required to be less than 1 500 g/m^2 after 28 freeze-thaw cycles.

B.6 Evaluation and attestation of conformity and CE-marking

B.6.1 General

National technical approvals as well as European Technical Approvals (ETA) contain the corresponding guidelines/regulations with regard to the evaluation and attestation of conformity and CE-marking. The following aspects are covered:

— system of attestation of conformity;

— tasks and responsibilities of the manufacturer and notified bodies;

— CE-marking and accompanying information.

Following – as an example – the provisions fixed for a limestone filler as a concrete addition are given. It is important to know, that these provisions only apply for one single limestone filler in combination with one single cement [2]:

B.6.2 Factory production control

In the manufacturing plant a factory production control is set up and performed. Factory production control is to be carried out by the manufacturer as a continuous monitoring of production, which ensures that the building products manufactured conform to the provisions of the Technical Approval [2].

The factory production control has to include at least the measures given in EN 12620 and the measures listed below:

- description and verification of the starting materials and the components;
- in addition to the tests given in EN 12620.

At least once a week:

- specific surface area.

At least once a month:

- $CaCO_3$ content;
- Clay content as determined by the methylene blue test according to EN 933-9;
- total organic carbon content (TOC);
- $MgCO_3$ content;
- content of water soluble chloride.

B.6.3 Third party inspection

In the factory, the production control has to be audited by a third party inspection on a regular basis, unless otherwise specified below, at least twice a year.

As part of the third party inspection an initial test of the construction products is carried out, samples have to be taken and to be tested, and samples can also be taken for sample testing. The inspection body is responsible for the sampling and testing. As part of the third party inspection in the production plant of the limestone filler, the following properties of the product have to be tested at least 4 times every year:

- $CaCO_3$ content;
- clay content as determined by the methylene blue test according to EN 933-9;
- total organic carbon content (TOC);
- particle size distribution;
- specific surface area.

As part of the third party inspection at the concrete plant, the following properties of the product have to be determined at least once a month:

- $CaCO_3$ content;
- clay content as determined by the methylene blue test according to EN 933-9;
- total organic carbon content (TOC);
- $MgCO_3$ content;
- 2d and 28d compressive strength (2 Prism sets with 82 % CEM I and 18 % limestone filler);
- stiffening;
- soundness.

B.6.4 Provisions for the use

National technical approvals also contain provisions for the use of the cement/addition in concrete.

Following – as an example – the provisions fixed for a limestone filler as a concrete addition are given. It is important to know, that these provisions only apply for one single limestone filler in combination with one single cement [2]:

- For the limestone covered by the technical approval, the proof of the equivalent concrete performance according to EN 206-1, 5.2.5.3 is established for a combination with at least mass fraction of 82 % Portland cement CEM I according to EN 197-1 of a certain origin of the strength class 42,5 N or higher.

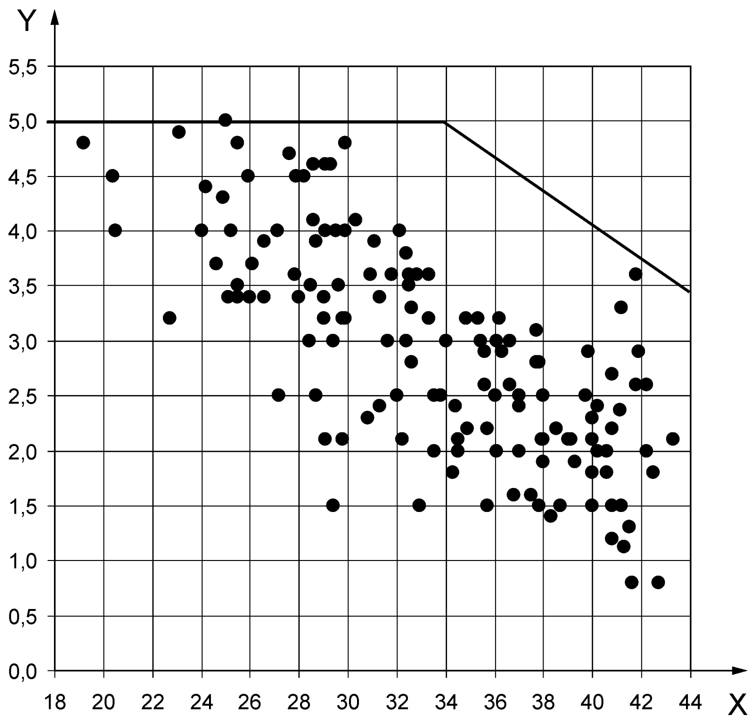
- The combination of up to mass fraction of 18 % limestone filler and at least mass fraction of 82 % Portland cement CEM I as described before may be used in concrete according to EN 206-1 / DIN 1045-2 similar to the existing regulations in Table F.3.1 for the cement type CEM II / A-LL according to EN 197-1, but not in the Exposure classes XF2 and XF4.
- The sum of the amounts of Portland cement and limestone filler according to the technical approval shall be at least meet the minimum cement content given in DIN 1045-2 2008, Table F.2.1 and F.2.2, line 3.
- In addition to EN 206-1 / DIN 1045-2:2008, Table 22 the starting materials, are to be tested according to Table B.5.

Table B.5 — Additional control of the concrete constituents [2]

	Concrete starting material	Inspection/ test	Purpose	Minimum frequency
1	Cement	Reference samples	Keep up the until strength test performed or to the agreed time	each delivery prior to concrete production
10a	Addition	Limestone filler conforming to EN 12620: — $CaCO_3$ content, — Clay content as determined by the methylene blue test according to EN 933-9; — Content of total organic carbon (TOC); — $MgCO_3$ content	Conformity to the requirements of technical approval for $CaCO_3$, clay content and TOC	monthly
16	Cement/ Addition	2 d, 28 d compressive strength (2 Prism sets with 82 % CEM I + 18 % limestone filler)	Conformity to the requirements for the strength class 42,5 R according to EN 197-1	for weekly or less frequent delivery: per delivery, otherwise at least two times per production week

B.7 Evaluation of the carbonation resistance – Version: February 2012

In Figure B.1 to Figure B.4 results from the approval testing for the verification of the carbonation behaviour of different cements (CEM I, CEM II/A-LL, CEM III/B, CEM II/B-M (S-V), CEM II/B V, CEM II/B-M (SV-LL)) are given.

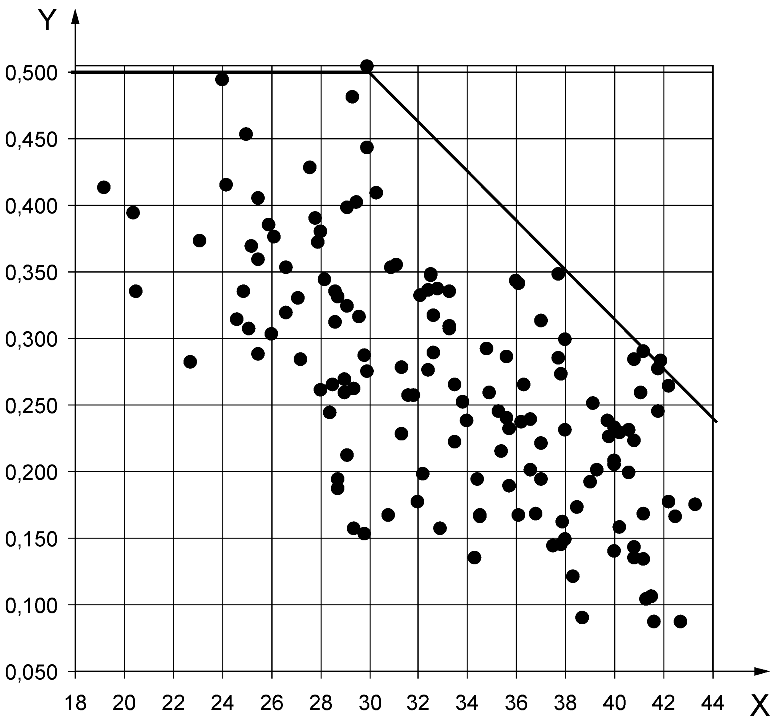


Key

X compressive strength after pre-storage in N/mm^2

Y carbonation depth $d_{C,140d}$ in mm

Figure B.1 — Carbonation depths (7 days pre-storage) at 140 days exposure in the climate chamber

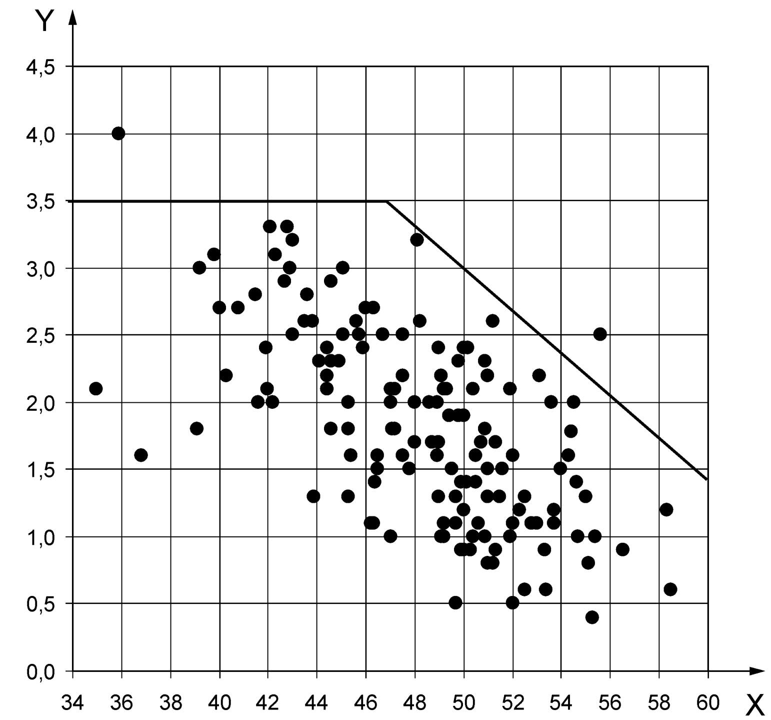


Key

X Compressive strength after pre-storage in N/mm^2

Y Carbonation speed $v_{C,140d}$ in mmxd$^{-0,5}$

Figure B.2 — Rate of carbonation (7 days pre-storage) after 140 days exposure in climate chamber

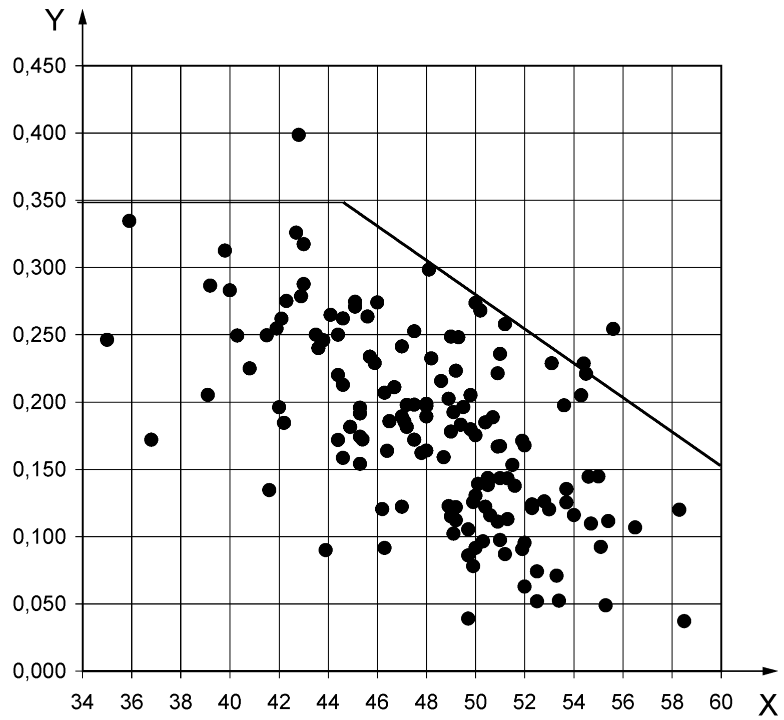


Key

X compressive strength after pre-storage in N/mm^2

Y carbonation depth $d_{C,140d}$ in mm

Figure B.3 — Carbonation depths (28 days pre-storage) at 140 days exposure in the climate chamber



Key

X carbonation speed $v_{C,140d}$ in mmxd$^{-0,5}$

Y carbonation depth $d_{C,140d}$ in mm

Figure B.4 — Rate of carbonation (28 days pre-storage) at 140 days exposure in the climate chamber

Annex C
(informative)

Italy

EDP is not implemented as a fully developed procedure in the Italian regulation and voluntary standards. However, a performance concept is included in the Italian regulation [3] concerning the use of additions in concrete. In particular fly ash conforming to EN 450-1, silica fume conforming to EN 13263-1 and ground granulated blast furnace conforming to EN 15167-1 are permitted on the basis of durability performance testing. To assess concrete permeability to aggressive agents two tests are used. These tests are the depth of water penetration under pressure in accordance with EN 12390-8 and resistivity [4].

To meet durability requirements, it is recommended that concrete has permeability coefficient K equal or lower than $1 \cdot 10^{-11}$ m/s or penetration resistance to water with a maximum value not higher than 50 mm and mean value not higher than 20 mm according to EN 12390-8. For resistivity, the recommended value is ≥ 100 000 Ohm·cm and it is strongly advised that it should be not less than 10 000 Ohm·cm.

Annex D
(informative)

The Netherlands

NEN-EN 1992-1-1 (Eurocode 2) is the design standard under the Dutch Law ("Bouwbesluit") [5] for concrete constructions. For the calculation values of concrete reference is made to the concrete cube strength as determined according to NEN-EN 206-1:2012, 5.5.1.1 and 5.5.1.2. At the same time in NEN-EN 206-1:2012, 5.2.5.3 the equivalent concrete performance (ECP) concept is introduced. This concept permits amendments to the requirements for minimum cement content and maximum water/cement ratio when a combination of a specific addition and a specific cement is used. It has to be proven that the concrete has an equivalent performance especially with respect to its reaction to environmental actions and to its durability when compared with a reference concrete conforming to the requirements for the relevant exposure class.

NEN-EN 206-1 has to be used in combination with NEN 8005 (the Dutch NAD). NEN 8005 defines the minimum cement content and maximum water-cement ratio in relation to the exposure classes.

In the Netherlands the procedure, criteria and test methods for the assessment of the equivalent concrete performance (their EDP) are given in the National Guideline CUR-Recommendation 48 (in Dutch) [6].

CUR-Recommendation 48 applies to the assessment of the suitability of a combination of one or more specific additions and cements for application in concrete. To demonstrate the equivalent performance of the candidate concrete, one or more durability aspects have to be tested (carbonation, chloride penetration, freeze/thaw-resistance with de-icing salts, sea-water resistance and sulphate attack) depending on the exposure class. In addition the concrete strength at 7 days and 28 days of the candidate concrete is part of the assessment. Other mechanical properties (as tensile strength, bending strength, elastic modulus, shrinkage, creep) do not have to be tested. In structural codes these properties are related to the compressive strength. Since the composition of cement-addition combinations is similar to that of common cements, the relation between compressive strength and other mechanical properties will also be similar.

The composition of the candidate concrete is required to conform to the following requirements:

a) the minimum clinker content shall be mass fraction of 20 % for the combination of Portland cement with slag and mass fraction of 25 % for other combinations;

b) the maximum limestone content of a cement-addition combination shall be mass fraction of 35 %;

c) the binder content shall be equal or larger than the minimum cement content for the applicable exposure class, as defined by NEN 8005;

d) the water/binder ratio shall be lower than or equal to the maximum water/cement ratio for the applicable exposure class, as defined by NEN 8005.

The reference concrete has to conform to the requirements of NEN 8005 with a reference cement that is normally used in the applicable exposure class (defined in CUR-Recommendation 48).

The assessment of all durability aspects is based on the statistical comparison of minimum of 3 samples of the candidate and a minimum of 3 samples of the reference concrete. A t-test is applied using average and standard deviation of the test results. Approval or rejection is based on the difference in the test result between the candidate and reference concrete. Based on the following principle:

— the concrete producer or the supplier of the addition is obliged to demonstrate the suitability of the proposed concrete;

— for each durability aspect a maximum difference (d) between the mean values [%] is fixed that is considered acceptable. The choice of these d-values is based on expert opinion (defined in CUR-48);

— the consumer risk is fixed on 10 % at that difference.

The test methods (see Table D.1) have to be European- or national standards as defined in CUR-Recommendation 48.

Testing has to be undertaken by an independent laboratory that is accredited for the test-procedure.

The assessment (approval or rejection) is made by a Notified Body (e.g. the certification institute).

Table D.1 — Test methods for the different durability aspects

Durability aspect	Test Standard	Accelerated ?	Concrete age at start test (days)	Test duration (days)
Carbonation	Rilem CPC 18	NO	3	91/ 182/ 364
	prCEN/TS 12390-XX:2008	YES	42	56/ 63/ 70
Chloride ingress	NT Build 443	NO	31	35
	NT Build 492	YES	28/ 56/ 91/ 182/ 364	1 – 2
Freeze-Thaw (with de-icing salts)	NPR-CEN/TS 12390-9	NO	28	7
Sulfate resistance	Dutch method	NO	28	364
Seawater resistance	Dutch method	NO	28	364

Annex E
(informative)

Norway

Prescriptive “limiting values” requirements for 8 cement types, used alone or in combination with silica fume, fly ash or GGBS are given in the Norwegian National Annex to EN 206-1 replacing Table F.1.

For cement types

(1) CEM I, CEM II/A-D and CEM II/ A-V provisions are given for use in all exposure classes

(2) CEM II/A-S provisions are given for all exposure classes except for XF2, XF3 and XF4

(3) CEM II/B-S, CEM II/B-V and CEM III/A provisions are given for all exposure classes except XC and XF

(4) CEM II/A-L provisions are given for all exposure classes except for XD, XS, XF and XA

To allow some flexibility to import and use of cements without a successful record in the Norwegian market, some additional provisions are given.

The National Annex, Clause NA.5.3.2 allows the user to demonstrate a minimum performance for cements in group (2), (3) and (4) concerning freeze-thaw resistance. The requirement is given as maximum scaling tested in TS-12390-9 with salt solution after 56 or 112 cycles.

For slag blended cements with more than 35 % GGBS, the test specimen shall be carbonated at least 2 mm before testing.

The national Annex, Clause NA.5.3.2 allows the user to demonstrate equal or better performances for group (3) compared to one of the cements in group (1) concerning carbonation resistance tested according to EN 13295, but with prolonged exposure period to 16 weeks, alternatively according to CEN/TS 12390-10 (2 years).

For group (4) Clause NA.5.3.2 2 allows the user to demonstrate equal or better performances compared to a cement in group (1) concerning chloride resistance tested according to EN 13396 (concentration increased to 6%) or EN 13396 (exposure period increased to 2 years).

CEN/TS 12390-11 was not available when this clause was written.

In no cases less strict requirements are allowed than those valid in the country where the actual cement was produced.

The demonstration of equivalence shall be certified by the certification body certifying the concrete producer (only one certification body is active in the Norwegian market).

Cements not listed among the 8 types above, shall be handled case-by-case by the standardization body.

Annex F
(normative)

The system used in Portugal and defined in their national annex to EN 206-1

F.1 General

In Portugal, the suitability of the concept of equivalent performance of concrete is established in the specification LNEC E 464 “Concrete. Prescriptive methodology for a design working life of 50 and of 100 years under environmental exposure classes XC, XD and XS [7], in accordance to EN 206-1:2000, 5.2.5.3. The concept allows the use of different limiting value requirements (minimum cement content and maximum W/C) than those established in the above Specification.

The Portuguese approach does not make use of Stage 2 to take into account ageing effects, being conservative to the extent that identifies reference cements (see Clause F.3) with recognised better performance to resist those environmental actions. The choice of other constituents is under the responsibility of the concrete producer, but they shall be used in both the reference and candidate concretes.

F.2 Properties and test methods

The properties to be assessed for the establishment of equivalent performance are presented in Table F.1.

Table F.1 — Properties, methods and test specimens

Exposure classes	Properties to be determined	Test methods	Number and size of specimens (mm)
XC 1 XC 2 XC 3 XC 4	Accelerated carbonation	LNEC E 391	1 specimen 150 × 150 × 600
	Oxygen permeability	LNEC E 392	3 specimens ϕ=150; h=50
	Compressive strength	NP EN 12390-3	3 specimens of 150 × 150 × 150
XS1/XD1 XS2/XD2 XS3/XD3	Chloride diffusion coefficient	LNEC E 463	2 specimens ϕ=100; h=50
	Capillary absorption	LNEC E 393	3 specimens ϕ=150; h=50
	Compressive strength	NP EN 12390-3	3 specimens of 150 × 150 × 150

The accelerated carbonation is measured in a climate chamber with a CO_2 concentration of 5 % and RH = (60 ± 5) %, the oxygen permeability test (LNEC E 392) follows the CEMBUREAU recommendation (1989) [8], the chloride diffusion coefficient (LNEC E 463) is determined by a migration test (NT BUILD 492) and the capillary absorption (LNEC E 393) is in accordance with a RILEM recommendation (1982) [9]. The tests are carried out at 28 days in an accredited laboratory.

In the manufacturing and curing of specimens, both as regards the reference and candidate concretes, the procedures indicated in the EN 12350-1 and EN 12390-2 shall be adopted, except in the case of specimens intended for accelerated carbonation, oxygen permeability and capillary absorption tests, of which the cure, after 7 days, is done as follows:

- accelerated carbonation: 7 days at (20 ± 2) ºC without humidity exchanges, keeping the specimens in a sealed container adjusted to their size, e.g. Tupperware, followed by 14 days at (20 ± 2) ºC and at (65 ± 5) % of relative humidity;
- permeability to oxygen and capillary absorption: after surface drying with a cloth, 3 day drying at (50 ± 2) ºC in a ventilated oven, followed by 17 days at (50 ± 2) ºC and 1 day at (20 ± 2) ºC, there being no humidity exchange in these 18 days, by keeping the specimens in a sealed container adjusted to their size.

F.3 Materials and mixes

The materials to be used in the reference and candidate concretes shall have their suitability established as concrete constituents and shall be supplied by the concrete producer. The cement to be used in the reference concrete is CEM I for XC classes and CEM IV/A for XD and XS classes. The coarse aggregates and the corresponding fractions shall be the same in the reference concrete as in the candidate concrete.

The reference and candidate concrete mixes are under the responsibility of the concrete producer, the testing laboratory being responsible for verifying if the reference mix fulfils the requirements regarding the maximum water/cement ratio, the minimum cement content and the minimum strength class of the concrete, according to the environmental exposure class considered. The target compressive strength is f_{ck} +8 MPa.

In each reference and candidate mixes, the testing laboratory will vary by ± 5 % the binder content, maintaining the content of the other constituents except for the fine aggregate, which is varied to maintain the yield.

The potential changes in the mixes for adjusting the mixing water shall be proposed by the concrete producer. The consistency (slump) of reference and candidate concrete mixes shall not differ, on average, more than 10 mm, and the individual values shall fulfil the limits of the same slump class.

F.4 Analysis of results and report

The results obtained on the reference concrete mixes are then compared with the corresponding values of the candidate concrete mixes, which on average shall be numerically equal or better than the reference concrete. If the results make it possible to conclude about the equivalence, the concrete manufacturer is allowed to use for the tested exposure classes the new minimum binder content value and the new maximum W/C ratio value as composition limits, provided that the constituents undergo no alteration, both as regards their source and as regards their relevant characteristics.

The tests shall be performed at least every 3 years and whenever alterations occur in the binder or in the other concrete constituents that may adversely affect the performance of the candidate concrete.

Annex G
(informative)

Spain

In Spain, there is a Regulation (legal requirement) for concrete production and calculation of structures: the “Instruction of Structural Concrete” EHE-08 [10]. It has the same scope than the EN 206, EN 13670:2010 and EN 1992-1-1 all together. For the cement types it cites the RC-08 [11] “Instruction for the reception of cements” that it is also a regulatory document in Spain. And for the concrete producers, there is a current Ministerial Order. This legal level indicates that the responsibility for the safety aspects regarding concrete is the competence of the State.

The EHE-08 contains the normal requirements and specifications to take into account concrete durability in the main chapters and it has an Annex 9 through which it is possible to specify concrete composition/type by its performance. Then, EHE-08 explicitly provides a procedure to make Equivalent Durability Performance in carbonation and chloride penetration, concerning reinforcement durability.

There are two alternative ways to verify service life:

- through deemed-to-satisfy rules (following the EHE-08 requirements);
- by performance (following the EHE-08, Annex 9 procedure).

In both cases the responsibility of the designer is defined in EHE-08.

The procedure to verify service life comprises fulfilling the following steps:

a) Define service life for the structure and its elements (the EHE-08 has an indicative table with number of years depending on the importance of the structure).

b) Identify exposure class(es) and from these and the service life:

   1)) Define cover depth in structural elements for the case of reinforcement corrosion.

c) Select in a table the concrete provisions of minimum cement content/maximum water/cement ratio and the recommended nominal concrete strength. Additionally the limitations on deleterious substances, e.g. chlorides are identified and specified

   1) If the cover depth is desired to be changed, then EHE-08, Annex 9 enables other combinations of constituents for fabricating the concrete providing the Project Manager accepts these changes. EHE-08, Annex 9 indicates some durability models for some specific type of attacks such as for carbonation and for chloride penetration. No requirements are made in EHE-08, Annex 9 on the type of tests to be used to conform to the parameters of the models.

Concrete aging is implicitly taken into account in the EHE-08 by permitting lower concrete covers for some type of cements and some additions. In the specific case of the chloride attack model, EHE-08, Annex 9 allows the use of an aging factor of the chloride diffusion coefficient based on cement type.

At the voluntary level, in AENOR (through the Committee on Concrete AEN/CTN-83/SC10: Durability*),* at the date of the writing this Annex (Sept 2012), it is being developed a technical report on "Durability of concrete. Strategy of durability verification. Part X: Calculation of service life through the electrical resistivity" that will propose for the durability design regarding reinforcement corrosion a method based on the measurement of the electrical resistivity of concrete specimens cured in the same manner as for mechanical strength. The method comprises:

i) measuring the resistivity at 3, 7,14 and 28 days in order to obtain the aging factor q and the nominal resistivity at 28 days;

ii) obtaining a reaction factor, $r_{Cl,CO2}$ from the measurement of the porosity and:

   I) a natural chloride diffusion test lasting 90 days after 28 days curing or

   II) for carbonation from a test after 28 days curing with the sample exposed to natural conditions (sheltered or not sheltered from rain) for a period of 3 months to 12 months.

It is accepted that Equivalent Durability Performance has been achieved when the apparent resistivity, ρ_{ap} calculated for 28 days $\rho_{ap} = r_{Cl,CO2} \cdot \rho_{ef}$ (or any other age agreed) is statistically the same.

$$\rho_{ap}(t) = r_{Cl,CO2} \cdot \rho_{ef} \cdot \left(\frac{t_0}{t_n}\right)^q$$

The ρ_{ef} is the resistivity measured in a concrete sample cured in humid conditions for 28 days (i.e. the same conditions as for mechanical strength).

Annex H
(informative)

United Kingdom

The UK has not adopted an EDP as described in this report. In the UK there is a normative procedure set out in BS 8500-1 for the combination of CEM I with either:

a) fly ash conforming to EN 450-1:2012 category A or B;

b) ggbs conforming to EN 15167-1;

c) limestone fines conforming to BS 7979.

General suitability is only established for those combinations of the same nominal proportions as CEM II/A-L or LL, CEM II/A-S, CEM II/B-S, CEM II/A-V, CEM II/B-V CEM III/A, CEM III/B and CEM IV/B(V) where they are tested and certified to meet the compressive strength class 22,5, 32,5, 42,5 and 52,5 as set out in EN 14216 or EN 197-1. To meet the certified strength class the proportion of fly ash, ggbs or limestone may be less than the maximum proportions permitted by EN 14216 or EN 197-1. Under these strict conditions the combination is considered equivalent to the EN 197-1 cement of the same nominal proportions. Consequently when used in the same concrete specification as permitted for the cement type, equivalent durability is assumed. This approach avoids the need for durability testing.

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