BRITISH STANDARD

BS EN
206-1:2000
Incorporating
Corrigendum No. 1

Concrete —

Part 1: Specification, performance, production and conformity

The European Standard EN 206-1:2000 has the status of a British Standard

ICS 91.100.30

National foreword

This British Standard is the official English language version of EN 206-1:2000. It supersedes DD ENV 206:1992 which is withdrawn.

It is intended that this British Standard be used in conjunction with the complementary standards BS 8500-1, BS 8500-2, BS 8500-3 and BS 8500-4 which, when published, will give national provisions where they are permitted in EN 206-1:2000 and these standards will supersede BS 5328-1:1997, BS 5328-2:1997, BS 5328-3:1990 and BS 5328-4:1990 which will be withdrawn in December 2003.

The UK participation in its preparation entrusted by Technical Committee B/517, Concrete, to Subcommittee B/517/1, Concrete production and testing, which has the responsibility to:

— aid enquirers to understand the text;

— present to the responsible European committee any enquiries on the interpretation, or proposals for change, and keep the UK interests informed;

— monitor related international and European developments and promulgate them in the UK.

A list of organizations represented on this subcommittee can be obtained on request to its secretary.

This British Standard forms part of a package of related construction standards which include design and construction in concrete, concrete test methods, constituent materials for concrete and their test methods, standardized within CEN Member States. Although the official English language versions of these European Standards will be adopted as British Standards as they become available, the exsisting British Standards for the subject area will be retained, but only until such time as the complete package of European Standards becomes available.

Where a European Standard refers to another European Standard which is still in draft form, the equivalent British Standard may be used until superseded by the European Standard.

This British Standard, having been prepared under the direction of the Sector Committee for Building and Civil Engineering, was published under the authority of the Standards Committee and comes into effect on 15 February 2001

ISBN 0 580 36882 3

Amendments issued since publication

Amd. No.	Date	Comments
13189 Corrigendum No. 1	April 2001	Corrected and reprinted

Draft European Standards (prENs) referred to in this standard that have equivalent national standards are listed as follows:

prEN 1008:1997	BS 3148, *Methods of test for water for making concrete (including notes on the suitability of the water).*
prEN 12390-3:1999	BS 1881-116, *Testing concrete — Part 116: Method for determination of compressive strength of concrete cubes.*
prEN 12504-3:1999	BS 1881-201, *Testing concrete — Part 201: Guide to the use of non-destructive methods of test for hardened concrete.*
prEN 12504-4:1998	BS 1881-203, *Testing concrete — Part 203: Recommendations for measurement of velocity of ultrasonic pulses in concrete.*
prEN 12620:1996	BS 882, *Specification for aggregates from natural sources for concrete* and BS 1047, *Specification for air-cooled blast furnace slag aggregate for use in concrete.*
prEN 13055-1:1997	BS 3797, *Specification for lightweight aggregates for masonry units and structural concrete.*
prEN 13791:1999	BS 1881-201, *Testing concrete — Part 201: Guide to the use of non-destructive methods of test for hardened concrete.*

Some of the draft standards referred to in this standard have received negative votes by CEN at the formal vote stage, therefore the use of draft European Standards should be carefully considered.

The UK Technical Committee recommends that purchasers of concrete in the UK specify concrete that has been manufactured and supplied to a recognized third party product quality certification scheme.

Cross-references

The British Standards which implement international or European publications referred to in this document may be found in the BSI Standards Catalogue under the section entitled "International Standards Correspondence Index", or by using the "Find" facility of the BSI Standards Electronic Catalogue.

A British Standard does not purport to include all the necessary provisions of a contract. Users of British Standards are responsible for their correct application.

Compliance with a British Standard does not of itself confer immunity from legal obligations.

Summary of pages

This document comprises a front cover, an inside front cover, pages i and ii, the EN title page, pages 2 to 69 and a back cover.

The BSI copyright notice displayed in this document indicates when the document was last issued.

EUROPEAN STANDARD
NORME EUROPÉENNE
EUROPÄISCHE NORM

EN 206-1

December 2000

ICS 91.100.30

Supersedes ENV 206:1990

English version

Concrete — Part 1: Specification, performance, production and conformity

Béton — Partie 1: Spécification, performances, production et conformité

Beton — Teil 1: Festlegung, Eigenschaften, Herstellung und Konformität

This European Standard was approved by CEN on 12 May 2000.

CEN members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration. Up-to-date lists and bibliographical references concerning such national standards may be obtained on application to the Management Centre or to any CEN member.

This European Standard exists in three official versions (English, French, German). A version in any other language made by translation under the responsibility of a CEN member into its own language and notified to the Management Centre has the same status as the official versions.

CEN members are the national standards bodies of Austria, Belgium, Czech Republic, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Luxembourg, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland and United Kingdom.

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

Management Centre: rue de Stassart, 36 B-1050 Brussels

Ref. No. EN 206-1:2000 E

Contents

Figures

Tables

Foreword

This European Standard has been prepared by Technical Committee CEN/TC 104, Concrete and related products, the Secretariat of which is held by DIN.

This European Standard supersedes ENV 206:1990.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by June 2001, and conflicting national standards shall be withdrawn at the latest by December 2003.

According to the CEN/CENELEC Internal Regulations, the national standards organizations of the following countries are bound to implement this European Standard: Austria, Belgium, Czech Republic, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Luxembourg, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland and the United Kingdom

This standard together with parts of ENV 13670-1 (Execution of concrete structures) supersedes the European Pre-standard ENV 206:1990 "Concrete — Performance, production, placing and compliance criteria" which was the basis for the preparation of this standard.

In particular, the following items were subject to revision when preparing this standard:

— extension of the classification system for concrete especially with respect to environmental conditions;
— requirements for durability;
— extension of strength classes;
— strength classes for light-weight concrete;
— consideration of additions in the determination of the w/c ratio and the cement content;
— identification of division of technical responsibility between the specifier, producer and user;
— reconsideration of accuracy of weighing equipment;
— reconsideration of curing requirements;
— provisions for conformity control, conformity criteria and identity testing;
— provisions for the evaluation of conformity.

Aspects relating to the execution have, in general, been moved to ENV 13670-1 or other relevant standards.

The context in which this standard functions is illustrated in Figure 1.

This standard is only operable with product standards or equivalent specifications for constituent materials (i.e. cement, aggregates, additions, admixtures and mixing water) and related test methods for concrete. Product standards and test method standards are under preparation by CEN but they will not all be available as European Standards at the date of publication of this standard. For this reason, the latest date of withdrawal of national standards (dow) conflicting with this standard will be the date when all standards listed below, together with the related standards for test methods, are available and implemented as European Standards or ISO Standards where appropriate or have the status required by this standard.

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

EN 12620, *Aggregates for concrete including those for use in roads and pavements*

EN 13055-1, *Light-weight aggregates — Part 1: Light-weight aggregates for concrete and mortar*

EN 1008, *Mixing water for concrete — Specifications for sampling, testing and assessing the suitability of water, including wash water from recycling installations in the concrete industry, as mixing water for concrete*

EN 934-2, *Admixtures for concrete, mortar and grout — Part 2: Concrete admixtures — Definitions and requirements*

EN 450, *Fly ash for concrete — Definitions, requirements and quality control*

EN 13263, *Silica fume for concrete — Definitions, requirements and conformity control*

The Annexes A, B and C are normative. The Annexes D, E, F, G, H, J and K are informative.

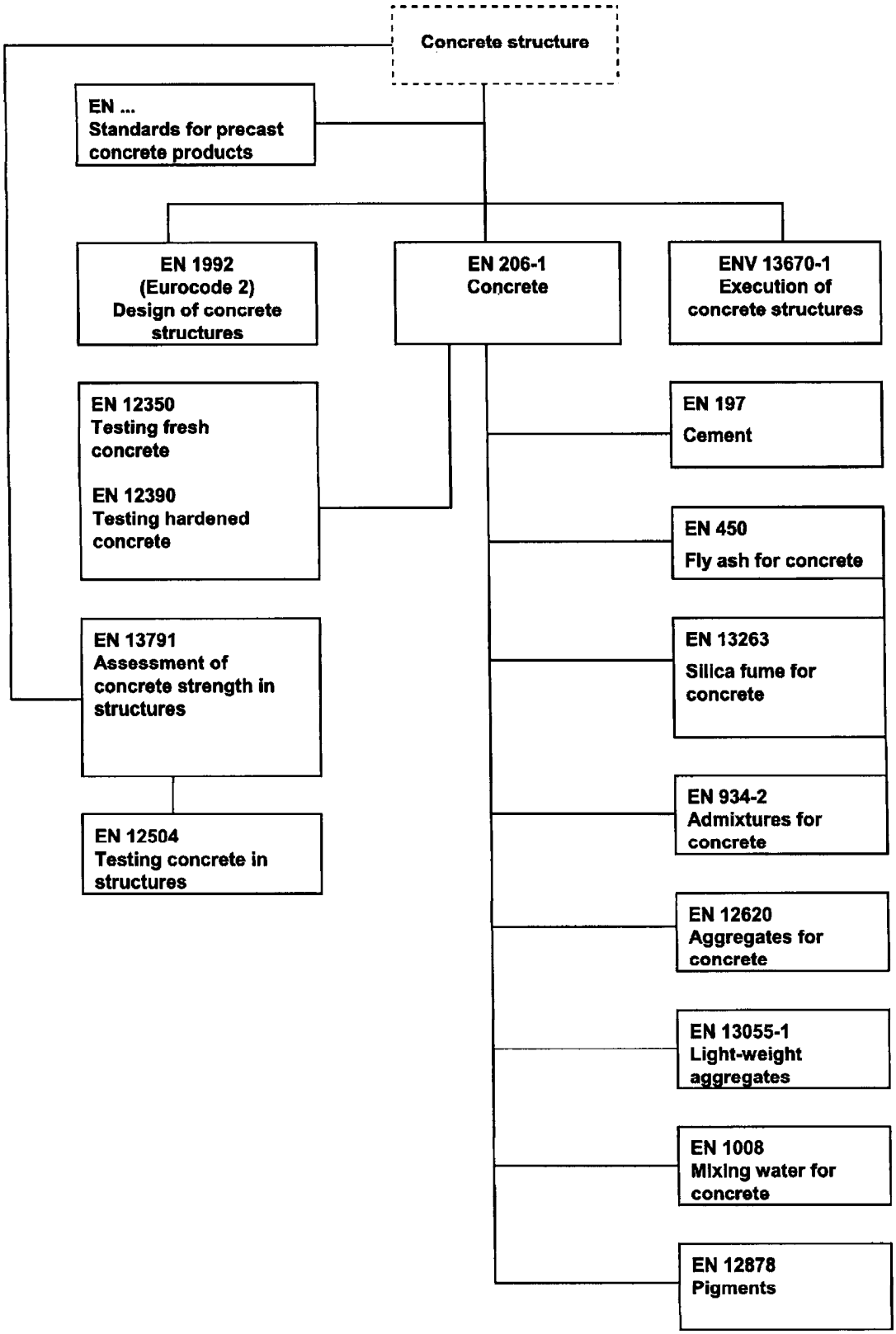


Figure 1 — Relationships between EN 206-1 and standards for design and execution, standards for constituent materials and test standards

Introduction

This European Standard will be applied in Europe under different climatic and geographical conditions, different levels of protection and under different, well established, regional traditions and experience. Classes for concrete properties have been introduced to cover these situations. Where such general solutions were not possible, the relevant clauses contain permission for the application of national standards or provisions valid in the place of use of the concrete.

During the development of this European Standard, consideration was given to detailing a performance-related approach to the specification of durability. For this, a review of performance-related design and test methods has been undertaken. However, CEN/TC 104 concluded that these methods are not yet sufficiently developed for them to be detailed in this standard, but CEN/TC 104 recognized that some CEN Members have developed confidence in local tests and criteria. Therefore this standard permits the continuation and development of such practices valid in the place of use of the concrete as an alternative to the prescriptive approach. CEN/TC 104 will continue to develop performance-related methods for assessing durability at the European level.

This European Standard incorporates rules for the use of constituent materials that are covered by European Standards. Other by-products of industrial processes, recycled materials etc. are in current use based on local experience. Until European specifications for these materials are available, this standard will not provide rules for their use, but instead refers to national standards or provisions valid in the place of use of the concrete.

This European Standard defines tasks for the specifier, producer and user. For example, the specifier is responsible for the specification of concrete, Clause 6, and the producer is responsible for conformity and production control, Clauses 8 and 9. The user is responsible for placing the concrete in the structure. In practice there may be several different parties specifying requirements at various stages of the design and construction process e.g. the client, the designer, the contractor, the concreting sub-contractor. Each is responsible for passing the specified requirements, together with any additional requirements, to the next party in the chain until they reach the producer. In the terms of this European Standard, this final compilation is known as the "specification". Conversely, the specifier, producer and user may be the same party (e.g. a contractor doing design and build). In the case of ready mixed concrete, the purchaser of the fresh concrete is the specifier and has to give the specification to the producer. This standard also covers the necessary exchange of information between the different parties. Contractual matters are not addressed. Where responsibilities are given for parties involved, these are technical responsibilities.

Notes and footnotes in tables of this standard are normative unless stated otherwise; other notes and footnotes are informative.

Further explanations and guidance on the application of this standard are given in other documents, such as CEN Reports.

1 Scope

This European Standard applies to concrete for structures cast in situ, precast structures, and structural precast products for buildings and civil engineering structures.

The concrete may be mixed on site, ready-mixed concrete or produced in a plant for precast concrete products.

This standard specifies requirements for:

— the constituent materials of concrete;
— the properties of fresh and hardened concrete and their verification;
— the limitations for concrete composition;
— the specification of concrete;
— the delivery of fresh concrete;
— the production control procedures;
— the conformity criteria and evaluation of conformity.

This European Standard applies to concrete compacted to retain no appreciable amount of entrapped air other than entrained air. This standard applies to normal-weight, heavy-weight and light-weight concrete.

Other European Standards for specific products e.g. precast products or for processes within the field of the scope of this standard may require or permit deviations from this standard.

Additional or different requirements may be given in further parts of this standard or in other specific European Standards, for example:

— concrete to be used in roads and other trafficked areas;
— concrete using other materials (e.g. fibres) or constituent materials not covered by 5.1;
— concrete with an upper aggregate size of 4 mm or less (mortar);
— special technologies (e.g. sprayed concrete);
— concrete for disposal of liquids and gaseous waste;
— concrete for vessels for storage of polluting substances;
— concrete for massive structures (e.g. dams);
— dry mixed concrete.

NOTE As long as these standards are not available, provisions valid in the place of use of the concrete may apply. European Standards are under preparation for:
— concrete to be used in roads and other trafficked areas;
— sprayed concrete.

This standard does not apply to:

— aerated concrete;
— foamed concrete;
— concrete with open structure ("no-fines" concrete);
— concrete with density less than 800 kg/m³;
— refractory concrete.

This standard does not cover health and safety requirements for the protection of workers during production and delivery of concrete.

2 Normative references

This European Standard incorporates by dated or undated reference, provisions from other publications. These normative references are cited at the appropriate places in the text and the publications are listed hereafter. For dated references, subsequent amendments to or revisions of any of these publications apply to this European Standard only when incorporated in it by amendment or revision. For undated references the latest edition of the publication referred to applies (including amendments).

In the case of reference to European draft standards, provisions valid in the place of use of the concrete may be applied until the European Standard is available.

EN 196-2, *Methods of testing cement — Part 2: Chemical analysis of cement*

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

EN 450, *Fly ash for concrete — Definitions, requirements and quality control*

EN 933-1, *Tests for geometrical properties of aggregates — Part 1: Determination of particle size distribution — Sieving method*

EN 934-2, *Admixtures for concrete, mortar and grout — Part 2: Concrete admixtures — Definitions and requirements*

prEN 1008:1997, *Mixing water for concrete — Specification for sampling, testing and assessing the suitability of water, including water recovered from processes in the concrete industry, as mixing water for concrete*

EN 1097-3, *Tests for mechanical and physical properties of aggregates — Part 3: Determination of loose bulk density and voids*

EN 1097-6, *Tests for mechanical and physical properties of aggregates — Part 6: Determination of particle density and water absorption*

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

EN 12350-2, *Testing fresh concrete — Part 2: Slump test*

EN 12350-3, *Testing fresh concrete — Part 3: Vebe test*

EN 12350-4, *Testing fresh concrete — Part 4: Degree of compactability*

EN 12350-5, *Testing fresh concrete — Part 5: Flow table test*

EN 12350-6, *Testing fresh concrete — Part 6: Density*

EN 12350-7, *Testing fresh concrete — Part 7: Air content of fresh concrete — Pressure methods*

EN 12390-1, *Testing hardened concrete — Part 1: Shape, dimensions and other requirements for test specimens and moulds*

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

prEN 12390-3:1999, *Testing hardened concrete — Part 3: Compressive strength of test specimens*

EN 12390-6, *Testing hardened concrete — Part 6: Tensile splitting strength of test specimens*

EN 12390-7, *Testing hardened concrete — Part 7: Density of hardened concrete*

prEN 12620:2000, *Aggregates for concrete*

EN 12878, *Pigments for colouring of building materials based on cement and/or lime — Specifications and methods of test*

prEN 13055-1:1997, *Lightweight aggregates — Part 1: Lightweight aggregates for concrete and mortar*

prEN 13263:1998, *Silica fume for concrete — Definitions, requirements and conformity control*

prEN 13577:1999, *Water quality — Determination of aggressive carbon dioxide content*

EN 45501:1992, *Metrological aspects of non-automatic weighing instruments*

ISO 2859-1:1999, *Sampling schemes for inspection by attributes — Part 1: Sampling schemes indexed by acceptance quality limit (AQL) for lot-by-lot inspection*

ISO 3951:1994, *Sampling procedures and charts for inspection by variables by percent nonconforming*

ISO 4316, *Surface active agents — Determination of pH of aqueous solutions — Potentiometric method*

ISO 7150-1, *Water quality — Determination of ammonium — Part 1: Manual spectrometric method*

ISO 7150-2, *Water quality — Determination of ammonium — Part 2: Automated spectrometric method*

ISO 7980, *Water quality — Determination of calcium and magnesium — Atomic absorption spectrometric method*

DIN 4030-2, *Assessment of water, soil and gases for their aggressiveness to concrete — Part 2: Collection and examination of water and soil samples*

ASTM C 173, *Test method for air content of freshly mixed concrete by the volumetric method*

OIML R 117, *Measuring systems for liquids(Organisation Internationale de Métrologie Légale)*

Directive 90/384/EEC, *Directive of the Council of 20 June 1990 for the harmonization of the regulations of the Member States concerning non-automatic weighing equipment*

3 Definitions, symbols and abbreviations

3.1 Terms and definitions

For the purposes of this standard, the following terms and definitions apply:

3.1.1
concrete
material formed by mixing cement, coarse and fine aggregate and water, with or without the incorporation of admixtures and additions, which develops its properties by hydration of the cement

3.1.2
fresh concrete
concrete which is fully mixed and still in a condition that is capable of being compacted by the chosen method

3.1.3
hardened concrete
concrete which is in a solid state and which has developed a certain strength

3.1.4
site-mixed concrete
concrete produced on the construction site by the user of the concrete for his own use

3.1.5
ready-mixed concrete
concrete delivered in a fresh state by a person or body who is not the user. Ready-mixed concrete in the sense of this standard is also:

— concrete produced off site by the user;

— concrete produced on site, but not by the user.

3.1.6
precast concrete product
concrete product cast and cured in a place other than the final location of use

3.1.7
normal-weight concrete
concrete having an oven-dry density greater than 2 000 kg/m^3 but not exceeding 2 600 kg/m^3

3.1.8
light-weight concrete
concrete having an oven-dry density of not less than 800 kg/m^3 and not more than 2 000 kg/m^3. It is produced using light-weight aggregate for all or part of the total aggregate

3.1.9
heavy-weight concrete
concrete having an oven-dry density greater than 2 600 kg/m^3

3.1.10
high strength concrete
concrete with a compressive strength class higher than C50/60 in the cases of normal-weight or heavy-weight concrete and LC50/55 in the case of light-weight concrete

3.1.11
designed concrete
concrete for which the required properties and additional characteristics are specified to the producer who is responsible for providing a concrete conforming to the required properties and additional characteristics

3.1.12
prescribed concrete
concrete for which the composition of the concrete and the constituent materials to be used are specified to the producer who is responsible for providing a concrete with the specified composition

3.1.13
standardized prescribed concrete
prescribed concrete for which the composition is given in a standard valid in the place of use of the concrete

3.1.14
concrete family
group of concrete compositions for which a reliable relationship between relevant properties is established and documented

3.1.15
cubic metre of concrete
quantity of fresh concrete which, when compacted in accordance with the procedure given in EN 12350-6, occupies a volume of one cubic metre

3.1.16
truck mixer
concrete mixer mounted on a self-propelled chassis capable of mixing and delivering a homogeneous concrete

3.1.17
agitating equipment
equipment generally mounted on a self-propelled chassis and capable of maintaining fresh concrete in a homogeneous state during transport

3.1.18
non-agitating equipment
equipment used for transporting concrete without agitation in the sense of definition 3.1.17, e.g. dump truck or transport hopper

3.1.19
batch
quantity of fresh concrete produced in one cycle of operations of a mixer or the quantity discharged during 1 min from a continuous mixer

3.1.20
load
quantity of concrete transported in a vehicle comprising one or more batches

3.1.21
delivery
process of handing over the fresh concrete by the producer

3.1.22
admixture
material added during the mixing process of concrete in small quantities related to the mass of cement to modify the properties of fresh or hardened concrete

3.1.23
addition
finely divided material used in concrete in order to improve certain properties or to achieve special properties. This standard deals with two types of inorganic additions:

— nearly inert additions (type I);

— pozzolanic or latent hydraulic additions (type II).

3.1.24
aggregate
granular mineral material suitable for use in concrete. Aggregates may be natural, artificial or recycled from material previously used in construction

3.1.25
normal-weight aggregate
aggregate with an oven-dry particle density > 2 000 kg/m^3 and < 3 000 kg/m^3, when determined according to EN 1097-6.

3.1.26
light-weight aggregate
aggregate of mineral origin having an oven-dry particle density ≤ 2 000 kg/m^3 when determined according to EN 1097-6 or a loose oven-dry bulk density ≤ 1 200 kg/m^3 when determined according to EN 1097-3

3.1.27
heavy-weight aggregate
aggregate having an oven-dry particle density ≥ 3 000 kg/m^3 when determined according to EN 1097-6

3.1.28
cement (hydraulic binder)
finely ground inorganic material which, when mixed with water, forms a paste that sets and hardens by means of hydration reactions and processes and which, after hardening, retains its strength and stability even under water

3.1.29
total water content
added water plus water already contained in the aggregates and on the surface of the aggregates plus water in the admixtures and in additions used in the form of a slurry and water resulting from any added ice or steam heating

3.1.30
effective water content
difference between the total water present in the fresh concrete and the water absorbed by the aggregates

3.1.31
water/cement ratio
ratio of the effective water content to cement content by mass in the fresh concrete

3.1.32
characteristic strength
value of strength below which 5 % of the population of all possible strength determinations of the volume of concrete under consideration, are expected to fall

3.1.33
entrained air
microscopic air bubbles intentionally incorporated in concrete during mixing, usually by use of a surface active agent; typically between 10 µm and 300 µm in diameter and spherical or nearly so

3.1.34
entrapped air
air voids in concrete which are not purposely entrained

3.1.35
site (construction site)
area where the construction work is undertaken

3.1.36
specification
final compilation of documented technical requirements given to the producer in terms of performance or composition

3.1.37
specifier
person or body establishing the specification for the fresh and hardened concrete

3.1.38
producer
person or body producing fresh concrete

3.1.39
user
person or body using fresh concrete in the execution of a construction or a component

3.1.40
working life
period of time during which the performance of the concrete in the structure will be kept at a level compatible with the fulfilment of the performance requirements of the structure, provided it is properly maintained

3.1.41
initial test
test or tests to check before the production starts how a new concrete or concrete family shall be composed in order to meet all the specified requirements in the fresh and hardened states

3.1.42
identity test
test to determine whether selected batches or loads come from a conforming population

3.1.43
conformity test
test performed by the producer to assess conformity of the concrete

3.1.44
evaluation of conformity
systematic examination of the extent to which a product fulfils specified requirements

3.1.45
environmental actions
those chemical and physical actions to which the concrete is exposed and which result in effects on the concrete or reinforcement or embedded metal that are not considered as loads in structural design

3.1.46
verification
confirmation by examination of objective evidence that specified requirements have been fulfilled

3.2 Symbols and abbreviations

X0	Exposure class for no risk of corrosion or attack
XC	Exposure classes for risk of corrosion induced by carbonation
XD	Exposure classes for risk of corrosion induced by chlorides other than from sea water
XS	Exposure classes for risk of corrosion induced by chlorides from sea water
XF	Exposure classes for freeze/thaw attack
XA	Exposure classes for chemical attack
S1 to S5	Consistence classes expressed by slump
V0 to V4	Consistence classes expressed by Vebe time
C0 to C3	Consistence classes expressed by degree of compactability
F1 to F6	Consistence classes expressed by flow diameter
C.../...	Compressive strength classes in case of normal-weight and heavy-weight concrete
LC.../...	Compressive strength classes in case of light-weight concrete
$f_{ck,cyl}$	Characteristic compressive strength of concrete determined by testing cylinders
$f_{c,cyl}$	Compressive strength of concrete determined by testing cylinders
$f_{ck,cube}$	Characteristic compressive strength of concrete determined by testing cubes
$f_{c,cube}$	Compressive strength of concrete determined by testing cubes
f_{cm}	Mean compressive strength of concrete
$f_{cm,j}$	Mean compressive strength of concrete at the age of (j) days
f_{ci}	Individual test result for compressive strength of concrete
f_{tk}	Characteristic tensile splitting strength of concrete
f_{tm}	Mean tensile splitting strength of concrete
f_{ti}	Individual test result for tensile splitting test of concrete
D	Density class of light-weight concrete
D_{max}	Maximum nominal upper aggregate size
CEM	Cement type according to the series EN 197
σ	Estimate for the standard deviation of a population
s_n	Standard deviation of n consecutive test results
AQL	Acceptance quality level (see ISO 2859-1)
w/c	Water/cement ratio
k	Factor which takes into account the activity of a type II addition
e	Verification scale interval of weighing equipment
m	Load exerted on weighing equipment
n	Number

4 Classification

4.1 Exposure classes related to environmental actions

The environmental actions are classified as exposure classes in Table 1. The given examples are informative.

NOTE The exposure classes to be selected depend on the provisions valid in the place of use of the concrete. This exposure classification does not exclude consideration of special conditions existing in the place of use of the concrete or the application of protective measures such as the use of stainless steel or other corrosion resistant metal and the use of protective coatings for the concrete or the reinforcement.

The concrete may be subject to more than one of the actions described in Table 1 and the environmental conditions to which it is subjected may thus need to be expressed as a combination of exposure classes.

Table 1 — Exposure classes

Class designation	Description of the environment	Informative examples where exposure classes may occur
1 No risk of corrosion or attack		
X0	For concrete without reinforcement or embedded metal: all exposures except where there is freeze/thaw, abrasion or chemical attack For concrete with reinforcement or embedded metal: very dry	Concrete inside buildings with very low air humidity.
2 Corrosion induced by carbonation		
Where concrete containing reinforcement or other embedded metal is exposed to air and moisture, the exposure shall be classified as follows: NOTE The moisture condition relates to that in the concrete cover to reinforcement or other embedded metal, but in many cases, conditions in the concrete cover can be taken as reflecting that in the surrounding environment. In these cases classification of the surrounding environment may be adequate. This may not be the case if there is a barrier between the concrete and its environment.		
XC1	Dry or permanently wet	Concrete inside buildings with low air humidity. Concrete permanently submerged in water.
XC2	Wet, rarely dry	Concrete surfaces subject to long-term water contact. Many foundations.
XC3	Moderate humidity	Concrete inside buildings with moderate or high air humidity. External concrete sheltered from rain.
XC4	Cyclic wet and dry	Concrete surfaces subject to water contact, not within exposure Class XC2.
3 Corrosion induced by chlorides other than from sea water		
Where concrete containing reinforcement or other embedded metal is subject to contact with water containing chlorides, including de-icing salts, from sources other than from sea water, the exposure shall be classified as follows: NOTE Concerning moisture conditions, see also section 2 of this table.		
XD1	Moderate humidity	Concrete surfaces exposed to airborne chlorides.
XD2	Wet, rarely dry	Swimming pools. Concrete exposed to industrial waters containing chlorides.
XD3	Cyclic wet and dry	Parts of bridges exposed to spray containing chlorides. Pavements. Car park slabs.

Table 1 — Exposure classes *(continued)*

Class designation	Description of the environment	Informative examples where exposure classes may occur
4 Corrosion induced by chlorides from sea water		
Where concrete containing reinforcement or other embedded metal is subject to contact with chlorides from sea water or air carrying salt originating from sea water, the exposure shall be classified as follows:		
XS1	Exposed to airborne salt but not in direct contact with sea water	Structures near to or on the coast
XS2	Permanently submerged	Parts of marine structures
XS3	Tidal, splash and spray zones	Parts of marine structures
5 Freeze/thaw attack with or without de-icing agents		
Where concrete is exposed to significant attack by freeze/thaw cycles whilst wet, the exposure shall be classified as follows:		
XF1	Moderate water saturation, without de-icing agent	Vertical concrete surfaces exposed to rain and freezing
XF2	Moderate water saturation, with de-icing agent	Vertical concrete surfaces of road structures exposed to freezing and airborne de-icing agents
XF3	High water saturation, without de-icing agent	Horizontal concrete surfaces exposed to rain and freezing
XF4	High water saturation, with de-icing agent or sea water	Road and bridge decks exposed to de-icing agents. Concrete surfaces exposed to direct spray containing de-icing agents and freezing. Splash zones of marine structures exposed to freezing.
6 Chemical attack		
Where concrete is exposed to chemical attack from natural soils and ground water as given in Table 2, the exposure shall be classified as given below. The classification of sea water depends on the geographical location, therefore the classification valid in the place of use of the concrete applies. NOTE A special study may be needed to establish the relevant exposure condition where there is: — limits outside of Table 2; — other aggressive chemicals; — chemically polluted ground or water; — high water velocity in combination with the chemicals in Table 2.		
XA1	Slightly aggressive chemical environment according to Table 2	
XA2	Moderately aggressive chemical environment according to Table 2	
XA3	Highly aggressive chemical environment according to Table 2	

Table 2 — Limiting values for exposure classes for chemical attack from natural soil and ground water

The aggressive chemical environments classified below are based on natural soil and ground water at water/soil temperatures between 5 °C and 25 °C and a water velocity sufficiently slow to approximate to static conditions.

The most onerous value for any single chemical characteristic determines the class.

Where two or more aggressive characteristics lead to the same class, the environment shall be classified into the next higher class, unless a special study for this specific case proves that it is not necessary.

Chemical characteristic	Reference test method	XA1	XA2	XA3
Ground water				
SO_4^{2-} mg/l	EN 196-2	≥ 200 and ≤ 600	> 600 and ≤ 3 000	> 3 000 and ≤ 6 000
pH	ISO 4316	≤ 6,5 and ≥ 5,5	< 5,5 and ≥ 4,5	< 4,5 and ≥ 4,0
CO_2 mg/l aggressive	prEN 13577:1999	≥ 15 and ≤ 40	> 40 and ≤ 100	> 100 up to saturation
NH_4^+ mg/l	ISO 7150-1 or ISO 7150-2	≥ 15 and ≤ 30	> 30 and ≤ 60	> 60 and ≤ 100
Mg^{2+} mg/l	ISO 7980	≥ 300 and ≤ 1 000	> 1 000 and ≤ 3 000	> 3 000 up to saturation
Soil				
SO_4^{2-} mg/kg[a] total	EN 196-2[b]	≥ 2 000 and ≤ 3 000[c]	> 3 000[c] and ≤ 12 000	> 12 000 and ≤ 24 000
Acidity ml/kg	DIN 4030-2	> 200 Baumann Gully	Not encountered in practice	

[a] Clay soils with a permeability below 10^{-5} m/s may be moved into a lower class.

[b] The test method prescribes the extraction of SO_4^{2-} by hydrochloric acid; alternatively, water extraction may be used, if experience is available in the place of use of the concrete.

[c] The 3 000 mg/kg limit shall be reduced to 2 000 mg/kg, where there is a risk of accumulation of sulfate ions in the concrete due to drying and wetting cycles or capillary suction.

4.2 Fresh concrete

4.2.1 Consistence classes

Where the consistence of concrete is classified, Tables 3, 4, 5 or 6 apply.

NOTE The classes of consistence in Tables 3 to 6 are not directly related. In special cases, consistence may also be specified by target value. For earth moist concrete, i.e. concrete with low water content designed to be compacted in special processes, the consistence is not classified.

Table 3 — Slump classes

Class	Slump in mm
S1	10 to 40
S2	50 to 90
S3	100 to 150
S4	160 to 210
S5[1)]	≥ 220

Table 4 — Vebe classes

Class	Vebe time in seconds
V0[1)]	≥ 31
V1	30 to 21
V2	20 to 11
V3	10 to 6
V4[1)]	5 to 3

[1)] See note to 5.4.1.

Table 5 — Compaction classes

Class	Degree of compactability
C0[1)]	≥ 1,46
C1	1,45 to 1,26
C2	1,25 to 1,11
C3	1,10 to 1,04

Table 6 — Flow classes

Class	Flow diameter in mm
F1[1)]	≤ 340
F2	350 to 410
F3	420 to 480
F4	490 to 550
F5	560 to 620
F6[1)]	≥ 630

4.2.2 Classes related to maximum aggregate size

Where concrete is classified according to the maximum size of aggregate, the nominal upper aggregate size of the coarsest fraction (D_{max}) in the concrete shall be used for classification.

NOTE D is the upper sieve size by which the aggregate size is defined in accordance with prEN 12620:2000.

4.3 Hardened concrete

4.3.1 Compressive strength classes

Where concrete is classified with respect to its compressive strength, Table 7 for normal-weight and heavy-weight concrete or Table 8 for light-weight concrete apply. The characteristic compressive strength at 28 days of 150 mm diameter by 300 mm cylinders ($f_{ck,cyl}$) or the characteristic compressive strength at 28 days of 150 mm cubes ($f_{ck,cube}$) may be used for classification.

NOTE In special cases intermediate strength levels between those in Table 7 or 8 may be used if this is permitted by the relevant design standard.

Table 7 — Compressive strength classes for normal-weight and heavy-weight concrete

Compressive strength class	Minimum characteristic cylinder strength $f_{ck,cyl}$ N/mm^2	Minimum characteristic cube strength $f_{ck,cube}$ N/mm^2
C8/10	8	10
C12/15	12	15
C16/20	16	20
C20/25	20	25
C25/30	25	30
C30/37	30	37
C35/45	35	45
C40/50	40	50
C45/55	45	55
C50/60	50	60
C55/67	55	67
C60/75	60	75
C70/85	70	85
C80/95	80	95
C90/105	90	105
C100/115	100	115

1) See note to 5.4.1.

Table 8 — Compressive strength classes for light-weight concrete

Compressive strength class	Minimum characteristic cylinder strength $f_{ck,cyl}$ N/mm^2	Minimum characteristic cube strength[a] $f_{ck,cube}$ N/mm^2
LC8/9	8	9
LC12/13	12	13
LC16/18	16	18
LC20/22	20	22
LC25/28	25	28
LC30/33	30	33
LC35/38	35	38
LC40/44	40	44
LC45/50	45	50
LC50/55	50	55
LC55/60	55	60
LC60/66	60	66
LC70/77	70	77
LC80/88	80	88

[a] Other values may be used if the relationship between these and the reference cylinder strength is established with sufficient accuracy and is documented.

4.3.2 Density classes for light-weight concrete

Where light-weight concretes are classified by density classes, Table 9 applies.

Table 9 — Classification of light-weight concrete by density

Density class	D1,0	D1,2	D1,4	D1,6	D1,8	D2,0
Range of density kg/m^3	≥ 800 and ≤ 1 000	> 1 000 and ≤ 1 200	> 1 200 and ≤ 1 400	> 1 400 and ≤ 1 600	> 1 600 and ≤ 1 800	> 1 800 and ≤ 2 000

NOTE The density of light-weight concrete may also be specified by target value.

5 Requirements for concrete and methods of verification

5.1 Basic requirements for constituent materials

5.1.1 General

Constituent materials shall not contain harmful ingredients in such quantities as may be detrimental to the durability of the concrete or cause corrosion of the reinforcement and shall be suitable for the intended use in concrete.

Where general suitability is established for a constituent material, this does not indicate suitability in every situation and for every concrete composition.

Only constituents with established suitability for the specified application shall be used in concrete conforming to EN 206-1.

NOTE Where there is no European Standard for a particular constituent material which refers specifically to the use of this constituent material in concrete conforming to EN 206-1, or where there is an existing European Standard which does not cover the particular product or where the constituent deviates significantly from the European Standard, the establishment of suitability may result from:

— a European Technical Approval which refers specifically to the use of the constituent material in concrete conforming to EN 206-1;

— a relevant national standard or provisions valid in the place of use of the concrete which refers specifically to the use of the constituent material in concrete conforming to EN 206-1.

5.1.2 Cement

General suitability is established for cement conforming to EN 197-1.

5.1.3 Aggregates

General suitability is established for:

— normal and heavy-weight aggregates conforming to prEN 12620:2000;

— lightweight aggregates conforming to prEN 13055-1:1997.

NOTE Provisions for recycled aggregates are not yet included in these standards. Until provisions for recycled aggregates are given in European technical specifications, suitability should be established according to the note in 5.1.1.

5.1.4 Mixing water

Suitability is established for mixing water and for recycled water from concrete production conforming to prEN 1008:1997.

5.1.5 Admixtures

General suitability is established for admixtures conforming to EN 934-2.

5.1.6 Additions (including mineral fillers and pigments)

General suitability as type I addition, see 3.1.23, is established for:

— filler aggregate conforming to prEN 12620:2000;

— pigments conforming to EN 12878.

General suitability as type II addition, see 3.1.23, is established for:

— fly ash conforming to EN 450;

— silica fume conforming to prEN 13263:1998.

5.2 Basic requirements for composition of concrete

5.2.1 General

The concrete composition and the constituent materials for designed or prescribed concrete shall be chosen (see 6.1) to satisfy the requirements specified for fresh and hardened concrete, including consistence, density, strength, durability, protection of embedded steel against corrosion, taking into account the production process and the intended method of execution of concrete works.

Where not detailed in the specification, the producer shall select types and classes of constituent materials from those with established suitability for the specified environmental conditions.

NOTE 1 The concrete should be designed so as to minimize segregation and bleeding of the fresh concrete unless specified otherwise.

NOTE 2 The required properties of concrete in the structure will generally only be achieved if certain execution procedures on the fresh concrete are fulfilled at the place of use. Therefore, in addition to the requirements of this standard, the requirements for transportation, placing, compaction, curing and further treatment should be taken into account before specifying the concrete (see ENV 13670-1 or other relevant standards). Many of these requirements are often interdependent. If all these requirements are satisfied, any difference in concrete quality between the concrete in the structure and standardized test specimens will be adequately covered by the partial safety factor for the material (see ENV 1992-1-1).

For standardized prescribed concrete, the composition is restricted to:

— natural normal-weight aggregate;

— additions in powder form provided they are not taken into account for the cement content and water/cement ratio;

— admixtures except for air-entraining admixtures;

— compositions fulfilling the criterion for adoption of initial tests given in A.5.

NOTE 3 *Provisions valid in the place of use may list types and classes of constituent materials with established suitability for the local environment.*

5.2.2 Selection of cement

The cement shall be selected from those for which the suitability is established, taking into account the:

— execution of the work;

— end use of the concrete;

— curing conditions (e.g. heat treatment);

— dimensions of the structure (the heat development);

— environmental conditions to which the structure is to be exposed (see 4.1);

— potential reactivity of aggregate to the alkalis from the constituents.

5.2.3 Use of aggregates

5.2.3.1 General

Aggregate type, grading and categories, e.g. flakiness, freeze/thaw resistance, abrasion resistance, fines, shall be selected taking into account the:

— execution of the work;

— end use of the concrete;

— environmental conditions to which the concrete is to be exposed;

— any requirements for exposed aggregate or aggregate for tooled concrete finishes.

— The maximum nominal upper aggregate size (D_{max}) shall be selected taking into account the cover to reinforcement and the minimum section width.

5.2.3.2 All-in aggregate

All-in aggregate conforming to prEN 12620:2000 shall be used only in concrete with compressive strength classes ≤ C12/15.

5.2.3.3 Recovered aggregate

Aggregate recovered from wash water or fresh concrete may be used as aggregate for concrete.

Undivided recovered aggregate shall not be added in quantities greater than 5 % of the total aggregate. Where the quantities of the recovered aggregates are greater than 5 % of the total aggregate, they shall be of the same type as the primary aggregate and shall be divided into separate coarse and fine fractions and conform to prEN 12620:2000.

5.2.3.4 Resistance to alkali-silica reaction

Where aggregates contain varieties of silica susceptible to attack by alkalies (Na_2O and K_2O originating from cement or other sources) and the concrete is exposed to humid conditions, actions shall be taken to prevent deleterious alkali-silica reaction using procedures of established suitability.

NOTE Precautions appropriate to the geological sources of the aggregates should be followed, taking into account long term experience with the particular combination of cement and aggregate. A survey of these precautions that are valid in different European countries, is given in CEN Report CR 1901.

5.2.4 Use of recycled water

Recycled water from concrete production shall be used in accordance with the conditions specified for its use in prEN 1008:1997.

5.2.5 Use of additions

5.2.5.1 General

The quantities of type I and type II additions to be used in concrete shall be covered by the initial tests (see Annex A).

NOTE 1 The influence of high quantities of additions on properties other than strength should be taken into account.

Type II additions may be taken into account in the concrete composition with respect to the cement content and the water/cement ratio if the suitability is established.

The suitability of the *k*-value concept is established for fly ash and silica fume (see 5.2.5.2). If other concepts e. g. the equivalent concrete performance concept (see 5.2.5.3), modifications of the rules of the *k*-value concept, higher *k*-values as defined in 5.2.5.2.2 and 5.2.5.2.3, other additions (including type I) or combinations of additions are to be used, their suitability shall be established.

NOTE 2 The establishment of the suitability may result from either:
- a European Technical Approval which refers specifically to the use of the addition in concrete conforming to EN 206-1;
- a relevant national standard or provision valid in the place of use of the concrete which refers specifically to the use of the addition in concrete conforming to EN 206-1.

5.2.5.2 *k*-value concept

5.2.5.2.1 General

The *k*-value concept permits type II additions to be taken into account:

- by replacing the term "water/cement ratio" (defined in 3.1.31) with "water/(cement + k × addition) ratio";
- in the minimum cement content requirement (see 5.3.2).

The actual value of *k* depends on the specific addition.

The application of the *k*-value concept for fly ash conforming to EN 450 or silica fume conforming to prEN 13263:1998 together with cement of type CEM I conforming to EN 197-1 is given in the following clauses. The *k*-value concept may be applied to fly ash or silica fume with other types of cement and to other additions if there is established suitability.

5.2.5.2.2 *k*-value concept for fly ash conforming to EN 450

The maximum amount of fly ash to be taken into account for the *k*-value concept shall meet the requirement:

fly ash/cement ≤ 0,33 by mass.

If a greater amount of fly ash is used, the excess shall not be taken into account for the calculation of the water/(cement + k × fly ash) ratio, and the minimum cement content.

The following *k*-values are permitted for concrete containing cement type CEM I conforming to EN 197-1:

CEM I 32,5	k = 0,2
CEM I 42,5 and higher	k = 0,4

The minimum cement content required for the relevant exposure class (see 5.3.2) may be reduced by a maximum amount of k × (minimum cement content – 200) kg/m^3 and additionally the amount of (cement + fly ash) shall not be less than the minimum cement content required in accordance with 5.3.2.

NOTE The *k*-value concept is not recommended for concrete containing a combination of fly ash and sulfate resisting CEM I cement in the case of exposure Classes XA2 and XA3 when the aggressive substance is sulfate.

5.2.5.2.3 *k*-value concept for silica fume conforming to prEN 13263:1998

The maximum amount of silica fume to be taken into account for the water/cement ratio and the cement content shall meet the requirement:

silica fume/cement ≤ 0,11 by mass.

If a greater amount of silica fume is used, the excess shall not be taken into account for the *k*-value concept.

The following *k*-values are permitted to be applied for concrete containing cement type CEM I conforming to EN 197-1:

for specified water/cement ratio	≤ 0,45	k = 2,0
for specified water/cement ratio	> 0,45	k = 2,0 except for exposure Classes XC and XF, where k = 1,0.

The amount of (cement + k × silica fume) shall be not less than the minimum cement content required for the relevant exposure class (see 5.3.2). The minimum cement content shall not be reduced by more than 30 kg/m^3 in concrete for use in exposure classes for which the minimum cement content is ≤ 300 kg/m^3.

5.2.5.3 Equivalent concrete performance concept

The equivalent concrete performance concept permits amendments to the requirements in this standard for minimum cement content and maximum water/cement ratio when a combination of a specific addition and a specific cement is used, for which the manufacturing source and characteristics of each are clearly defined and documented.

Within the requirements of 5.2.5.1, it shall 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 in accordance with the requirements for the relevant exposure class (see 5.3.2).

Annex E gives the principles for the assessment of the equivalent concrete performance concept. Where concrete is produced according to these procedures, it shall be subject to continual assessment which takes into account variations in the cement and the addition.

Subject to the above provisions, the equivalent concrete performance concept of established suitability may be applied (see note 2 in 5.2.5.1).

5.2.6 Use of admixtures

The total amount of admixtures, if any, shall not exceed the maximum dosage recommended by the admixture producer and not exceed 50 g of admixture (as supplied) per kg cement unless the influence of the higher dosage on the performance and the durability of the concrete is established.

Admixtures used in quantities less than 2 g/kg cement are only permitted if they are dispersed in part of the mixing water.

If the total quantity of liquid admixtures exceeds 3 l/m^3 of concrete, its water content shall be taken into account when calculating the water/cement ratio.

Where more than one admixture is used, the compatibility of the admixtures shall be checked in the initial tests.

NOTE Concrete with consistence ≥ S4, V4, C3 or ≥ F4 should be made with high range water reducing/super plasticizing admixture.

5.2.7 Chloride content

The chloride content of a concrete, expressed as the percentage of chloride ions by mass of cement, shall not exceed the value for the selected class given in Table 10.

Table 10 — Maximum chloride content of concrete

Concrete use	Chloride content class[a]	Maximum Cl^- content by mass of cement[b]
Not containing steel reinforcement or other embedded metal with the exception of corrosion-resisting lifting devices	Cl 1,0	1,0 %
Containing steel reinforcement or other embedded metal	Cl 0,20	0,20 %
	Cl 0,40	0,40 %
Containing prestressing steel reinforcement	Cl 0,10	0,10 %
	Cl 0,20	0,20 %

[a] For a specific concrete use, the class to be applied depends upon the provisions valid in the place of use of the concrete.

[b] Where type II additions are used and are taken into account for the cement content, the chloride content is expressed as the percentage chloride ion by mass of cement plus total mass of additions that are taken into account.

Calcium chloride and chloride based admixtures shall not be added to concrete containing steel reinforcement, prestressing steel reinforcement or other embedded metal.

For the determination of the chloride content of the concrete, the sum of the contributions from the constituent materials shall be determined using one of, or a combination of, the following methods:

— calculation based on the maximum chloride content of the constituent either permitted in the standard for the constituent or declared by the producer of each constituent material;
— calculation based on the chloride content of the constituent materials calculated monthly from the sum of the means of the last 25 determinations of chloride content plus 1,64 × the calculated standard deviation for each constituent material.

NOTE The latter method is particularly applicable to sea-dredged aggregates and for those cases where there is no declared or standard maximum value.

5.2.8 Concrete temperature

The temperature of fresh concrete shall not be less than 5 °C at the time of delivery. Where a requirement for a different minimum temperature or a maximum temperature of fresh concrete is necessary, they shall be specified giving also tolerances. Any requirement for artificial cooling or heating of the concrete prior to delivery has to be agreed between the producer and the user.

5.3 Requirements related to exposure classes

5.3.1 General

Requirements for the concrete to withstand the environmental actions are given either in terms of limiting values for concrete composition and established concrete properties (see 5.3.2), or the requirements may be derived from performance-related design methods (see 5.3.3). The requirements shall take into account the intended working life of the concrete structure.

5.3.2 Limiting values for concrete composition

In the absence of European Standards for absolute performance testing of concrete, due to different long term experience, requirements for the method of specification to resist environmental actions are given in this standard in terms of established concrete properties and limiting values of composition.

NOTE 1 Due to the lack of experience on how the classification of the environmental actions on concrete reflect local differences in the same nominal exposure class, the specific values of these requirements for the applicable exposure classes are given in the provisions valid in the place of use.

The requirements for each exposure class shall be specified in terms of:

— permitted types and classes of constituent materials;

— maximum water/cement ratio;

— minimum cement content;

— minimum concrete compressive strength class (optional);

and if relevant:

— minimum air-content of the concrete.

NOTE 2 In the provisions valid in the place of use, the maximum water/cement ratio should be given in increments of 0,05, the minimum cement content in increments of 20 kg/m^3, the concrete compressive strength in classes as given in Table 7 for normal-weight and heavy-weight concrete and Table 8 for light-weight concrete. A recommendation for the choice of limiting values for concrete composition and properties is given in Annex F (informative) when using CEM I cement.

NOTE 3 The provisions valid in the place of use of the concrete should include requirements under the assumption of an intended working life of at least 50 years under the anticipated maintenance conditions. For shorter or longer working life, less onerous or more severe requirements may be necessary. In these cases or for specific concrete compositions or specific corrosion protection requirements for the concrete cover of the reinforcement (e.g. in the case of cover less than that specified in the relevant parts of ENV 1992-1 for corrosion protection), special considerations should be made by the specifier for a specific site or by national provisions in general.

If the concrete is in conformity with the limiting values, the concrete in the structure shall be deemed to satisfy the durability requirements for the intended use in the specific environmental condition, provided:

— the concrete is properly placed, compacted and cured e.g. in accordance with ENV 13670-1 or other relevant standards;

— the concrete has the minimum cover to reinforcement in accordance with the relevant design standard required for the specific environmental condition, e.g. ENV 1992-1;

— the appropriate exposure class was selected;

— the anticipated maintenance is applied.

5.3.3 Performance-related design methods

The requirements related to exposure classes may be established by using performance-related design methods for durability and may be specified in terms of performance-related parameters, e.g. scaling of concrete in a freeze/thaw test. Guidance on the use of an alternative performance-related design method with respect to durability is given in Annex J (informative). The application of an alternative method depends on the provisions valid in the place of use of the concrete.

5.4 Requirements for fresh concrete

5.4.1 Consistence

Where the consistence of concrete is to be determined, it shall be measured either by means of:

— slump test conforming to EN 12350-2;

— Vebe test conforming to EN 12350-3;

— degree of compactability conforming to EN 12350-4;

— flow table test conforming to EN 12350-5;

— specific methods to be agreed upon between the specifier and the producer for concrete for special applications (e.g. earth moist concrete).

NOTE Due to the lack of sensitivity of the test methods beyond certain values of consistence, it is recommended to use the indicated tests for:

— slump ≥ 10 mm and ≤ 210 mm;

— Vebe time ≤ 30 sec and > 5 sec;

— degree of compactibility ≥ 1,04 and < 1,46;

— flow diameter > 340 mm and ≤ 620 mm.

Where the consistence of concrete is to be determined, it shall be tested at the time of use of the concrete or in the case of ready-mixed concrete, at the time of delivery.

If concrete is delivered in a truck mixer or agitating equipment, the consistence may be measured using a spot sample obtained from the initial discharge. The spot sample shall be taken after a discharge of approximately 0,3 m^3 in accordance with EN 12350-1.

The consistence may be specified either by reference to a consistence class according to 4.2.1 or, in special cases, by a target value. For target values, the related tolerances are given in Table 11.

Table 11 — Tolerances for target values of consistence

Slump			
Target value in mm	≤ 40	50 to 90	≥ 100
Tolerance in mm	± 10	± 20	± 30
Vebe time			
Target value in sec	≥ 11	10 to 6	≤ 5
Tolerance in sec	± 3	± 2	± 1
Degree of compactability			
Target value	≥ 1,26	1,25 to 1,11	≤ 1,10
Tolerance	± 0,10	± 0,08	± 0,05
Flow diameter			
Target value in mm	all values		
Tolerance in mm	± 30		

5.4.2 Cement content and water/cement ratio

Where the cement, water, or addition content is to be determined, the cement content, addition content or added water shall be taken either as recorded on the print-out of the batch recorder or where recording equipment is not used, from the production record in connection with the batching instruction.

Where the water/cement ratio of concrete is to be determined, it shall be calculated on the basis of the determined cement content and the effective water content (for liquid admixtures see 5.2.6). The water absorption of normal-weight and heavy-weight aggregates shall be determined in accordance with EN 1097-6. The water absorption of coarse light-weight aggregate in the fresh concrete shall be taken as the value obtained at 1 hour based on the method given in Annex C of EN 1097-6, using the as-used moisture state instead of the oven-dry state.

NOTE 1 For fine light-weight aggregate, the test method and criteria should follow the provisions valid in the place of use of the concrete.

Where the minimum cement content is replaced by the minimum (cement + addition) content or the water/cement ratio is replaced by the water/(cement + $k \times$ addition) ratio or water/(cement + addition) ratio, (see 5.2.5) the method is to be applied with appropriate modifications.

No single value of water/cement ratio determination shall be greater than 0,02 above the limiting value.

Where the determination of the cement content, the addition content or water/cement ratio of fresh concrete by analysis is required, the test method and tolerances shall be agreed between the specifier and producer.

NOTE 2 See CEN Report CR 13902 "Determination of the water/cement ratio of fresh concrete".

5.4.3 Air content

Where the air content of the concrete is to be determined, it shall be measured in accordance with EN 12350-7 for normal-weight and heavy-weight concrete and in accordance with ASTM C 173 for light-weight concrete. The air content is specified by a minimum value. The upper limit on air content is the specified minimum value plus 4 % absolute.

5.4.4 Maximum aggregate size

Where the maximum nominal upper aggregate size of fresh concrete is to be determined, it shall be measured in accordance with EN 933-1.

The maximum nominal upper aggregate size as defined in prEN 12620:2000 shall not be greater than specified.

5.5 Requirements for hardened concrete

5.5.1 Strength

5.5.1.1 General

Where the strength is to be determined, it shall be based on tests carried out on either 150 mm cubes or 150/300 mm cylinders conforming to EN 12390-1 and made and cured in accordance with EN 12390-2 from samples taken in accordance with EN 12350-1.

In assessing the strength, other sizes of moulded specimens and other curing regimes may be used provided the relationship to those standardized has been established with sufficient accuracy and has been documented.

5.5.1.2 Compressive strength

Where the compressive strength is to be determined, it shall be expressed as $f_{c,cube}$ where determined using *cubical specimens* and $f_{c,cyl}$ where determined using cylindrical specimens, in accordance with prEN 12390-3:1999.

Whether the compressive strength is to be assessed on the basis of cube or cylinder tests shall be declared by the producer in due time before delivery. If a different method is to be used, this has to be agreed between the specifier and the producer.

Unless specified otherwise, the compressive strength is determined on specimens tested at 28 days. For particular uses, it may be necessary to specify the compressive strength at ages earlier or later than 28 days (e. g. for massive structural elements) or after storage under special conditions (e.g. heat treatment).

The characteristic strength of the concrete shall be equal to or greater than the minimum characteristic compressive strength for the specified compressive strength class, see Tables 7 and 8.

If the testing for compressive strength is expected to give non-representative values, e. g. when concrete of consistence Class C0 or stiffer than S1 or vacuum concrete is tested, either the test method shall be modified or the compressive strength may be assessed in the existing structure or structural component.

NOTE Assessing the strength in the structure or structural component should be based on prEN 13791:1999.

5.5.1.3 Tensile splitting strength

Where the tensile splitting strength of concrete is to be determined, it shall be measured in accordance with EN 12390-6. Unless specified otherwise, the tensile splitting strength is determined on specimens tested at 28 days.

The characteristic tensile splitting strength of the concrete shall be equal to or greater than the specified characteristic tensile splitting strength.

5.5.2 Density

According to its oven-dry density, concrete is defined as normal-weight concrete, light-weight concrete or heavy-weight concrete (see definitions).

Where the oven-dry density of concrete is to be determined, it shall be measured in accordance with EN 12390-7.

For normal-weight concrete, the oven-dry density shall be greater than 2 000 kg/m^3 and not exceed 2 600 kg/m^3. For light-weight concrete, the oven-dry density shall be within the limiting values for the specified density class, see Table 9. For heavy-weight concrete, the oven-dry density shall be greater than 2 600 kg/m^3. Where the density is specified as a target value, a tolerance of ± 100 kg/m^3 applies.

5.5.3 Resistance to water penetration

Where resistance to water penetration on test specimens is to be determined, the method and conformity criteria shall be agreed between the specifier and producer.

In the absence of an agreed test method, resistance to water penetration may be specified indirectly by limiting values for concrete composition.

5.5.4 Reaction to fire

Concrete which is composed of natural aggregates conforming to 5.1.3, cement conforming to 5.1.2, admixtures conforming to 5.1.5, additions conforming to 5.1.6 or other inorganic constituent materials conforming to 5.1.1, is classified as Euro Class A and does not require testing.[1)]

---

1) Commission decision of 9 September 1994 (94/611/EC) published in Official Journal of the European Communities No L 241/25, 9 September 1994

6 Specification of concrete

6.1 General

The specifier of the concrete shall ensure that all the relevant requirements for concrete properties are included in the specification given to the producer. The specifier shall also specify any requirements for concrete properties that are needed for transportation after delivery, placing, compaction, curing or further treatment. The specification shall, if necessary, include any special requirements (e.g. for obtaining an architectural finish).

The specifier shall take account of:

— the application of the fresh and hardened concrete;

— the curing conditions;

— the dimensions of the structure (the heat development);

— the environmental actions to which the structure is to be exposed;

— any requirements for exposed aggregate or tooled concrete finishes;

— any requirements related to the cover to reinforcement or minimum section width, e.g. maximum nominal upper aggregate size;

— any restrictions on the use of constituent materials with established suitability, e.g. resulting from exposure classes.

NOTE 1 The provisions valid in the place of use of the concrete may contain requirements for some of these considerations.

Concrete shall be specified either as designed concrete referring in general to classification given in Clause 4 and requirements given in 5.3 to 5.5 (see 6.2) or as prescribed concrete by prescribing the composition (see 6.3). The basis for designing or prescribing a concrete composition shall be results from initial tests (see Annex A) or information obtained from long-term experience with comparable concrete, taking into account the basic requirements for constituent materials (see 5.1) and concrete composition (see 5.2 and 5.3.2).

For prescribed concrete, the specifier is responsible for ensuring that the specification conforms to the general requirements in EN 206-1 and the specified composition is capable of achieving the intended performance of the concrete in both the fresh and hardened states. The specifier shall maintain and update supporting documentation relating the prescription to the intended performance, see 9.5. In the case of standardized prescribed concrete, this is the responsibility of the national standards organization.

NOTE 2 For prescribed concrete, the assessment of conformity is based solely on the achievement of the specified composition and not on any performance intended by the specifier.

6.2 Specification for designed concrete

6.2.1 General

Designed concrete shall be specified by means of basic requirements from 6.2.2, to be indicated in all cases, and additional requirements from 6.2.3, to be indicated where required.

For abbreviations to be used in specifications, see Clause 11.

6.2.2 Basic requirements

The specification shall contain:

a) a requirement to conform to EN 206-1;

b) compressive strength class;

c) exposure classes (see Clause 11 for the abbreviated format);

d) maximum nominal upper aggregate size;

e) chloride content class in accordance with Table 10.

In addition, for light-weight concrete:

f) density class or target density.

In addition, for heavy-weight concrete:

g) target density.

In addition, for ready-mixed concrete and site-mixed concrete:

h) consistence class or, in special cases, a target value for consistence.

6.2.3 Additional requirements

The following items may be specified using performance requirements and test methods where they are appropriate:

— special types or classes of cement (e.g. cement with low heat of hydration);
— special types or classes of aggregate;

NOTE 1 In these cases, concrete composition to minimize deleterious alkali-silica reaction is the responsibility of the specifier (see 5.2.3.4).

— characteristics required to resist freeze/thaw attack (e.g. air content, see 5.4.3);

NOTE 2 Before specifying the air content at delivery, the possible loss of air during pumping, placing, compacting etc. subsequent to the delivery should be taken into account by the specifier.

— requirements for the temperature of the fresh concrete where different from those in 5.2.8;
— strength development (see Table 12);
— heat development during hydration;
— retarded stiffening;
— resistance to water penetration;
— resistance to abrasion;
— tensile splitting strength (see 5.5.1.3);
— other technical requirements (e.g. requirements related to the achievement of a particular finish or special method of placing).

6.3 Specification for prescribed concrete

6.3.1 General

Prescribed concrete shall be specified by basic requirements from 6.3.2, to be indicated in all cases, and additional requirements from 6.3.3 to be indicated where required.

6.3.2 Basic requirements

The specification shall contain:

a) a requirement to conform to EN 206-1;

b) cement content;

c) cement type and strength class;

d) either w/c ratio or consistence in terms of class or, in special cases, a target value;

NOTE The specified value of the (target) w/c ratio should be 0,02 less than any required limiting value.

e) type, categories and maximum chloride content of aggregate; in the case of light-weight or heavy-weight concrete the maximum or minimum density of aggregate as appropriate;

f) maximum nominal upper size of aggregate and any limitations for grading;

g) type and quantity of admixture or addition, if any;

h) if admixtures or additions are used, sources of these constituents and of the cement as a substitute for characteristics that are not definable by other means.

6.3.3 Additional requirements

The specification may contain:

- sources of some, or all, concrete constituents as a substitute for characteristics that are not definable by other means;
- additional requirements for aggregates;
- requirements for the temperature of the fresh concrete where different from those in 5.2.8;
- other technical requirements.

6.4 Specification of standardized prescribed concrete

Standardized prescribed concrete shall be specified by citing:

- the standard valid in the place of use of the concrete giving the relevant requirements;
- the notation of the concrete in that standard.

Standardized prescribed concrete shall be used only for:

- normal-weight concrete for plain and reinforced concrete structures;
- compressive strength classes for design ≤ C16/20 unless strength Class C20/25 is permitted in provisions valid in the place of use of the concrete;
- exposure Classes X0 and XC1 unless provisions valid in the place of use of the concrete permit other exposure classes.

For restrictions on the composition of standardized prescribed concrete, see 5.2.1.

7 Delivery of fresh concrete

7.1 Information from the user of the concrete to the producer[1)]

The user shall agree with the producer the:

— delivery date, time and rate;

— and where appropriate inform the producer of:

— special transport on site;

— special methods of placing;

— limitation of delivery vehicle, e.g. type (agitating/non-agitating equipment), size, height or gross weight.

7.2 Information from the producer of the concrete to the user[1)]

The user may require information on the concrete composition to permit proper placing and curing of the fresh concrete as well as for estimating the strength development. Such information shall be given by the producer on request before delivery as appropriate. The following information shall be provided for designed concrete on request:

a) type and strength class of cement and type of aggregates;

b) type of admixtures, type and approximate content of additions, if any;

c) target water/cement ratio;

d) results of relevant previous tests for the concrete, e.g. from production control or from initial tests;

e) strength development;

f) sources of the constituent materials.

In the case of ready-mixed concrete, the information may also be provided, where requested, by reference to the producer's catalogue of concrete compositions in which details of strength classes, consistence classes, batch weights and other relevant data are given.

For the determination of curing time, information on the strength development of the concrete may be given either in terms of Table 12 or by a strength development curve at 20 °C between 2 and 28 days.

Table 12 — Strength development of concrete at 20 °C

Strength development	Estimate of strength ratio $f_{cm,2} / f_{cm,28}$
Rapid	≥ 0,5
Medium	≥ 0,3 to < 0,5
Slow	≥ 0,15 to < 0,3
Very slow	< 0,15

The strength ratio to indicate the strength development is the ratio of the mean compressive strength after 2 days ($f_{cm,2}$) to the mean compressive strength after 28 days ($f_{cm,28}$), determined from initial tests or based on known performance of concrete of comparable composition. For these initial tests, specimens for strength determination shall be sampled, made, cured and tested in accordance with EN 12350-1, EN 12390-1, EN 12390-2 and prEN 12390-3:1999.

The producer shall inform the user of health risks that may occur during handling the fresh concrete as required by the provisions valid in the place of use of the fresh concrete.

[1)] This standard does not require the information to be given in a specific format as this will depend on the relationship between the producer and the user, e.g. in the case of site-mixed concrete or precast concrete products, the producer and user of the concrete may be the same party.

7.3 Delivery ticket for ready-mixed concrete

At delivery, the producer shall provide the user with a delivery ticket for each load of concrete on which is printed, stamped or written at least the following information:

— name of the ready-mixed concrete plant;
— serial number of ticket;
— date and time of loading, i.e. time of first contact between cement and water;
— truck number or vehicle identification;
— name of purchaser;
— name and location of the site;
— details or references to specifications, e.g. code number, order number;
— amount of concrete in cubic metres;
— declaration of conformity with reference to the specifications and to EN 206-1;
— name or mark of the certification body if relevant;
— time at which the concrete arrives at the site;
— time of the beginning of unloading;
— time of the end of unloading.

In addition, the delivery ticket shall give details of the following:

a) for designed concrete:

— strength class;
— exposure classes;
— chloride content class;
— consistence class or target value;
— limiting values of concrete composition, if specified;
— type and strength class of cement, if specified;
— type of admixture and addition, if specified;
— special properties, if required;
— maximum nominal upper aggregate size;
— in case of light-weight or heavy-weight concrete: density class or target density.

b) for prescribed concrete:

— details of the composition, e.g. cement content, and, if required, type of admixture;
— either w/c ratio, or consistence in terms of class or target value, as specified;
— maximum nominal upper aggregate size.

In the case of standardized prescribed concrete, the information to be given shall follow the provisions of the relevant standard.

7.4 Delivery information for site-mixed concrete

Appropriate information as required in 7.3 for the delivery ticket is also relevant for site-mixed concrete where the site is large or several types of concrete are involved or where the party producing the concrete is different from the party who is responsible for placing the concrete.

7.5 Consistence at delivery

In general, any addition of water and admixtures at delivery is forbidden. In special cases, water or admixtures may be added where this is under the responsibility of the producer and used to bring the consistence to the specified value provided that the limiting values permitted by the specification are not exceeded and the addition of admixture is included in the design of the concrete. The quantity of any additional water or admixture added to the truck mixer shall be recorded on the delivery ticket in all cases. For re-mixing, see 9.8.

NOTE If more water or admixtures are added to the concrete in a truck mixer on site than is permitted by the specification, the concrete batch or load should be recorded as "non-conforming" on the delivery ticket. The party who authorized this addition is responsible for the consequences and this party should be recorded on the delivery ticket.

8 Conformity control and conformity criteria

8.1 General

Conformity control comprises the combination of actions and decisions to be taken in accordance with conformity rules adopted in advance to check the conformity of the concrete with the specification. Conformity control is an integral part of production control (see Clause 9).

NOTE The properties of concrete used for conformity control are those measured by the appropriate tests using standardized procedures. The actual values of the properties of the concrete in the structure may differ from those determined by the tests depending on, e.g. dimensions of the structures, placing, compaction, curing and climatic conditions.

The sampling and testing plan and conformity criteria shall conform to the procedures given in 8.2 or 8.3. These provisions apply also to concrete for precast products unless the specific product standard contains an equivalent set of provisions. If higher sampling rates are required by the specifier, this shall be agreed in advance. For properties not covered in these clauses, the sampling and testing plan, method of test and conformity criteria shall be agreed upon between the producer and the specifier.

The place of sampling for conformity tests shall be chosen such that the relevant concrete properties and concrete composition do not change significantly between the place of sampling and the place of delivery. In the case of light-weight concrete produced with unsaturated aggregates, the samples shall be taken at the place of delivery.

Where tests for production control are the same as those required for conformity control, they shall be permitted to be taken into account for the evaluation of conformity. The producer may also use other test data on the delivered concrete in the conformity assessment.

The conformity or non-conformity is judged against the conformity criteria. Non-conformity may lead to further action at the place of production and on the construction site (see 8.4).

8.2 Conformity control for designed concrete

8.2.1 Conformity control for compressive strength

8.2.1.1 General

For normal-weight and heavy-weight concrete of strength classes from C8/10 to C55/67 or light-weight concrete from LC8/9 to LC 55/60, sampling and testing shall be performed either on individual concrete compositions or on concrete families of established suitability (see 3.1.14) as determined by the producer unless agreed otherwise. The family concept shall not be applied to concrete with higher strength classes. Light-weight concrete shall not be mixed into families containing normal-weight concrete. Light-weight concrete with demonstrably similar aggregates may be grouped into its own family.

NOTE For guidance for the selection of concrete families, see Annex K. More detailed information for the application of the concrete family concept is given in CEN Report (13901).

In the case of concrete families, the producer shall achieve control over all family members and sampling shall be carried out across the whole range of concrete compositions produced within the family.

Where conformity testing is applied to a concrete family, a reference concrete is selected which is either that most commonly produced or one from the mid-range of the concrete family. Relationships are established between each individual concrete composition of the family and the reference concrete in order to be able to transpose test results for compressive strength from each individual concrete test result to the reference concrete. The relationships shall be reviewed on the basis of original compressive strength test data at every assessment period and when there are appreciable changes in the production conditions. In addition, when assessing conformity for the family, it has to be confirmed that each individual member belongs to the family (see 8.2.1.3).

In the sampling and testing plan and the conformity criteria of individual concrete compositions or concrete families, distinction is made between initial production and continuous production.

Initial production covers the production until at least 35 test results are available.

Continuous production is achieved when at least 35 test results are obtained over a period not exceeding 12 months.

If the production of an individual concrete composition, or a concrete family, has been suspended more than 12 months, the producer shall adopt the criteria, sampling and testing plan given for initial production.

During continuous production, the producer may adopt the sampling and testing plan and the criteria for initial production.

If the strength is specified for a different age, the conformity is assessed on specimens tested at the specified age.

Where identity of a defined volume of concrete with a population verified as conforming to the characteristic strength requirements is to be assessed, e.g. if there is doubt about the quality of a batch or load or if in special cases required by the project specification, this shall be in accordance with Annex B.

8.2.1.2 Sampling and testing plan

Samples of concrete shall be randomly selected and taken in accordance with EN 12350-1. Sampling shall be carried out on each family of concrete (see 3.1.14) produced under conditions that are deemed to be uniform. The minimum rate of sampling and testing of concrete shall be in accordance with Table 13 at the rate that gives the highest number of samples for initial or continuous production, as appropriate.

Notwithstanding the sampling requirements in 8.1, the samples shall be taken after any water or admixtures are added to the concrete under the responsibility of the producer, but sampling before adding placticizer or superplasticizer to adjust the consistence (see 7.5) is permitted where there is proof by initial testing that the plasticizer or superplasticizer in the quantity to be used has no negative effect on the strength of the concrete.

The test result shall be that obtained from an individual specimen or the average of the results when two or more specimens made from one sample are tested at the same age.

Where two or more specimens are made from one sample and the range of the test values is more than 15 % of the mean then the results shall be disregarded unless an investigation reveals an acceptable reason to justify disregarding an individual test value.

Table 13 — Minimum rate of sampling for assessing conformity

Production	Minimum rate of sampling		
	First 50 m^3 of production	Subsequent to first 50 m^3 of production[a]	
		concrete with production control certification	concrete without production control certification
Initial (until at least 35 test results are obtained)	3 samples	1/200 m^3 or 2/production week	1/150 m^3 or 1/production day
Continuous[b] (when at least 35 test results are available)		1/400 m^3 or 1/production week	

[a] Sampling shall be distributed throughout the production and should not be more than 1 sample within each 25 m^3.

[b] Where the standard deviation of the last 15 test results exceeds 1,37 σ, the sampling rate shall be increased to that required for initial production for the next 35 test results.

8.2.1.3 Conformity criteria for compressive strength

Conformity assessment shall be made on test results taken during an assessment period that shall not exceed the *last twelve months.*

Conformity of concrete compressive strength is assessed on specimens tested at 28 days[1)] in accordance with 5.5.1.2 for:

— groups of n non-overlapping or overlapping consecutive test results f_{cm} (Criterion 1);

— each individual test result f_{ci} (Criterion 2).

NOTE The conformity criteria are developed on the basis of non-overlapping test results. Application of the criteria to overlapping test results increases the risk of rejection.

Conformity is confirmed if both the criteria given in Table 14 for either initial or continuous production are satisfied.

Where conformity is assessed on the basis of a concrete family, Criterion 1 is to be applied to the reference concrete taking into account all transposed test results of the family; Criterion 2 is to be applied to the original test results.

To confirm that each individual member belongs to the family, the mean of all non-transposed test results (f_{cm}) for a single family member shall be assessed against Criterion 3 as given in Table 15. Any concrete failing this criterion shall be removed from the family and assessed individually for conformity.

Table 14 — Conformity criteria for compressive strength

Production	Number n of test results for compressive strength in the group	Criterion 1	Criterion 2
		Mean of n results (f_{cm}) N/mm²	Any individual test result (f_{ci}) N/mm²
Initial	3	$\geq f_{ck} + 4$	$\geq f_{ck} - 4$
Continuous	15	$\geq f_{ck} + 1{,}48\ \sigma$	$\geq f_{ck} - 4$

Table 15 — Confirmation criterion for family members

Number n of test results for compressive strength for a single concrete	Criterion 3
	Mean of n results (f_{cm}) for a single family member N/mm²
2	$\geq f_{ck} - 1{,}0$
3	$\geq f_{ck} + 1{,}0$
4	$\geq f_{ck} + 2{,}0$
5	$\geq f_{ck} + 2{,}5$
6	$\geq f_{ck} + 3{,}0$

Initially, the standard deviation shall be calculated from at least 35 consecutive test results taken over a period exceeding three months and which is immediately prior to the production period during which conformity is to be checked. This value shall be taken as the estimate of the standard deviation (σ) of the population. The validity of the adopted value has to be verified during the subsequent production. Two methods of verifying the estimate of the value of σ are permitted, the choice of the method shall be made in advance:

Method 1

The initial value of standard deviation may be applied for the subsequent period during which conformity is to be checked, provided the standard deviation of the latest 15 results (s_{15}) does not deviate significantly from the adopted standard deviation. This is considered valid provided:

— $0{,}63\ \sigma \leq s_{15} \leq 1{,}37\ \sigma$

— Where the value of s_{15} lies outside these limits, a new estimate of σ shall be determined from the last available 35 test results.

---

1) If the strength is specified for a different age the conformity is assessed on specimens tested at the specified age.

Method 2

— The new value of σ may be estimated from a continuous system and this value is adopted. The sensitivity of the system shall be at least that of Method 1.

The new estimate for σ shall be applied to the next assessment period.

8.2.2 Conformity control for tensile splitting strength

8.2.2.1 General

Clause 8.2.1.1 applies, but the concept of concrete families is not applicable. Each concrete composition shall be assessed separately.

8.2.2.2 Sampling and testing plan

Clause 8.2.1.2 applies.

8.2.2.3 Conformity criteria for tensile splitting strength

Where tensile splitting strength of concrete is specified, conformity assessment shall be made on test results taken during an assessment period that shall not exceed the last twelve months.

Conformity of concrete tensile splitting strength is assessed on specimens tested at 28 days, unless a different age is specified in accordance with 5.5.1.3 for:

— groups of n non-overlapping or overlapping consecutive test results f_{tm} (Criterion 1);

— each individual test result f_{ti} (Criterion 2).

Conformity with the characteristic tensile splitting strength (f_{tk}) is confirmed if the test results satisfy both the criteria in Table 16 for either initial or continuous production as appropriate.

Table 16 — Conformity criteria for tensile splitting strength

Production	Number n of results in the group	Criterion 1	Criterion 2
		Mean of n results (f_{tm}) in N/mm^2	Any individual test results (f_{ti}) in N/mm^2
Initial	3	$\geq f_{tk} + 0,5$	$\geq f_{tk} - 0,5$
Continuous	15	$\geq f_{tk} + 1,48\ \sigma$	$\geq f_{tk} - 0,5$

The provisions for the standard deviation given in Clause 8.2.1.3 shall be applied accordingly.

8.2.3 Conformity control for properties other than strength

8.2.3.1 Sampling and testing plan

Samples of concrete shall be randomly selected and taken in accordance with EN 12350-1. Sampling shall be carried out on each family of concrete produced under conditions that are deemed to be uniform. The minimum number of samples and the methods of test shall be in accordance with Tables 17 and 18.

8.2.3.2 Conformity criteria for properties other than strength

Where properties of concrete other than strength are specified, conformity assessments shall be made on running production over the assessment period that shall not exceed the last twelve months.

Conformity of concrete is based on counting the number of results obtained in the assessment period that lie outside the specified limiting values, class limits or tolerances on a target value and comparing this total with the maximum permitted number (method of attributes).

Conformity with the required property is confirmed if:

— the number of test results outside the specified limiting value, class limits or tolerances of target values, as appropriate, are not greater than the acceptance number in Tables 19a or 19b as given in Table 17 and 18. Alternatively in case of (AQL = 4 %), the requirement may be based on testing by variables in accordance with ISO 3951:1989 Table II-A (AQL = 4 %) where the acceptance number relates to Table 19a;

— all individual test results are within the maximum allowed deviation given in Table 17 or Table 18.

Table 17 — Conformity criteria for properties other than strength

Property	Test method or method of determination	Minimum number of samples or determinations	Acceptance number	Maximum allowed deviation of single test results from the limits of the specified class or from the tolerance on the target value	
				Lower limit	Upper limit
Density of heavy-weight concrete	EN 12390-7	as Table 13 for compressive strength	see Table 19a	–30 kg/m^3	no limit [a]
Density of light-weight concrete	EN 12390-7	as Table 13 for compressive strength	see Table 19a	–30 kg/m^3	+30 kg/m^3
Water/cement ratio	see 5.4.2	1 determination per day	see Table 19a	no limit [a]	+0,02
Cement content	see 5.4.2	1 determination per day	see Table 19a	–10 kg/m^3	no limit [a]
Air content of air-entrained fresh concrete	EN 12350-7 for normal-weight and heavy-weight concrete and ASTM C 173 for light-weight concrete	1 sample/production day when stabilized	see Table 19a	–0,5 % absolute value	+1,0 % absolute value
Chloride content of concrete	see 5.2.7	the determination shall be made for each concrete composition and shall be repeated if there is an increase in the chloride content of any of the constituents	0	no limit [a]	no higher value permitted

[a] Unless limits are specified.

Table 18 — Conformity criteria for consistence

Test method		Minimum number of samples or determinations	Acceptance number	Maximum allowed deviation[a] of single test results from the limits of the specified class or from the tolerance on the target value	
				Lower limit	Upper limit
Visual inspection	Comparison of the appearance with the normal appearance of concrete with the specified consistence	Each batch; for vehicle deliveries, each load	—	—	—
Slump	EN 12350-2	i) frequency as given in Table 13 for compressive strength ii) when testing air content iii) in case of doubt following visual inspection	see Table 19b	–10 mm	+20 mm
				–20 mm [b]	+30 mm [b]
Vebe time	EN 12350-3		see Table 19b	–4 sec	+2 sec
				–6 sec [b]	+4 sec [b]
Degree of compactability	EN 12350-4		see Table 19b	–0,05	+0,03
				–0,07 [b]	+0,05 [b]
Flow	EN 12350-5		see Table 19b	–15 mm	+30 mm
				–25 mm [b]	+40 mm [b]

[a] Where there is no lower or upper limit in the relevant consistence class, these deviations do not apply.
[b] Only applicable for consistence testing from initial discharge from truck mixer (see 5.4.1).

8.3 Conformity control of prescribed concrete including standardized prescribed concrete

Each batch of a prescribed concrete shall be assessed for conformity with the cement content, maximum nominal size and proportions of aggregates if specified and, where relevant, water/cement ratio, quantity of admixture or addition. The amount of cement, aggregate (each specified size), admixture and addition as recorded in the production record or the printout from the batch recorder shall be within the tolerances given in Table 21, and the water/cement ratio shall be within ±0,04 of the specified value. In the case of standardized prescribed concrete, the equivalent tolerances may be given in the relevant standard.

Where conformity of concrete composition is to be assessed by analysis of fresh concrete, the test methods and conformity limits shall be agreed between the user and the producer in advance, taking account of the above limits and the precision of the test methods.

Where conformity of the consistence is to be assessed, the relevant paragraphs of 8.2.3 and Table 18 apply.

For the:

— cement type and strength class;

— types of aggregates;

— type of admixture or addition, if any;

— sources of concrete constituents, where specified;

the conformity shall be assessed by comparison of the production record and the delivery documents for the constituents with the specified requirements.

Tables 19a and 19b — Acceptance numbers for conformity criteria for properties other than strength

Table 19a AQL = 4 %	
Number of test results	**Acceptance number**
1 - 12	0
13 - 19	1
20 - 31	2
32 - 39	3
40 - 49	4
50 - 64	5
65 - 79	6
80 - 94	7
95 - 100	8
Where the number of test results exceeds 100, the appropriate acceptance numbers may be taken from Table 2-A of ISO 2859-1:1999	

Table 19b AQL = 15 %	
Number of test results	**Acceptance number**
1 - 2	0
3 - 4	1
5 - 7	2
8 - 12	3
13 - 19	5
20 - 31	7
32 - 49	10
50 - 79	14
80 - 100	21

8.4 Actions in the case of non-conformity of the product

The following actions shall be taken by the producer in the event of non-conformity:

— check test results and if invalid, take action to eliminate errors;
— if non-conformity is confirmed e.g. by retesting, take corrective actions including a management review of relevant production control procedures;
— where there is confirmed non-conformity with the specification that was not obvious at delivery, give notice to the specifier and user in order to avoid any consequential damage;
— record actions on the items above.

If non-conformity of concrete results from addition of water or admixtures on site (see 7.5), the producer has to take actions only if he has authorized this addition.

NOTE If the producer has given notice of non-conformity of the concrete or if the results of conformity tests do not fulfil the requirements, supplementary testing according to EN 12504-1 on cores taken from the structure or components may be required or a combination of tests on cores and non-destructive tests on the structure or components, e.g. according to EN 12504-2 or prEN 12504-4:1999. Guidance for assessing the strength in the structure or in structural components is given in prEN 13791:1999.

9 Production control

9.1 General

All concrete shall be subject to production control under the responsibility of the producer.

Production control comprises all measures necessary to maintain the properties of concrete in conformity to specified requirements. It includes:

— selection of materials;
— concrete design;
— concrete production;
— inspections and tests;
— the use of the results of tests on constituent materials, fresh and hardened concrete and equipment;
— where relevant, inspection of equipment used in transporting fresh concrete;
— conformity control for which provisions are given in Clause 8.

The requirements for other aspects of production control are given in the following subclauses. These requirements shall be considered taking account of the kind and size of the production, the works, the particular equipment, procedures and rules in use at the place of production and use of the concrete. Additional requirements may be necessary for special circumstances at the production place or for specific requirements for particular structures or structural elements.

NOTE Clause 9 takes account of the principles of EN ISO 9001.

9.2 Production control systems

The responsibility, authority and the interrelation of all personnel who manage, perform and verify work affecting the quality of the concrete shall be defined in a documented production control system (production control manual). This particularly concerns personnel who need the organizational freedom and authority to minimize the risk of non-conforming concrete and to identify and record any quality problem.

The production control system shall be reviewed at least every two years by the management of the producer to ensure the suitability and effectiveness of the system. Records of such reviews shall be retained for at least 3 years unless legal obligations require a longer period.

The production control system shall contain adequately documented procedures and instructions. These procedures and instructions shall, where relevant, be established in respect of the control requirements as given in the Tables 22, 23 and 24. The intended frequencies of tests and inspections by the producer shall be documented. The results of tests and inspections shall be recorded.

9.3 Recorded data and other documents

All relevant data from the production control shall be recorded, see Table 20. The records of the production control shall be retained for at least 3 years unless legal obligations require a longer period.

Table 20 — Recorded data and other documents, where relevant

Subject	Recorded data and other documents
Specified requirements	Contract specification or summary of requirements.
Cements, aggregates, admixtures, additions	Name of suppliers and sources.
Tests on mixing water (not required for potable water)	Date and place of sampling. Test results.
Tests on constituent materials	Date and test results.
Composition of concrete	Concrete description. Record of masses of constituents in batch or load (e.g. cement content). Water/cement ratio. Chloride content. Code of family member.
Tests on fresh concrete	Date and place of sampling. Location in structure, if known. Consistence (method used and results). Density, where required. Concrete temperature, where required. Air content, where required. Volume of concrete batch or load tested. Number and codes of specimens to be tested. Water/cement ratio, where required.
Tests on hardened concrete	Date of testing. Code and ages of specimens. Test results for density and strength. Special remarks (e.g. unusual failure pattern of specimen).
Evaluation of conformity	Conformity/ non-conformity with specifications.
Additionally for ready mixed concrete	Name of purchaser. Location of work, e.g. the construction site. Numbers and dates of delivery tickets related to tests. Delivery tickets.
Additionally for precast concrete	Additional or different data may be required by the relevant product standard.

9.4 Testing

The testing shall be performed in accordance with the test methods given in this standard (reference test method) or other test methods may be used if the correlation or safe relationship between the results of these test methods and the reference methods have been established. The correctness of the safe relationship or correlation shall be examined at appropriate intervals.

The examination shall be carried out separately for each place of production that operates under different conditions, unless the relationship is given in national standards or provisions valid in the place of use.

9.5 Concrete composition and initial testing

In the case of using a new concrete composition, initial testing shall be performed to provide a concrete that achieves the specified properties or intended performance with an adequate margin (see Annex A). Where long term experience with a similar concrete or family is available, initial testing is not required. The concrete design and design relationships shall be re-established when there is a significant change in constituent materials. No initial testing by the producer is necessary in the case of a prescribed concrete or a standardized prescribed concrete.

New concrete compositions obtained by interpolation between known concrete compositions or extrapolations of compressive strength not exceeding 5 N/mm^2 are deemed to satisfy the requirements for initial testing.

Concrete compositions shall be reviewed periodically to provide assurance that all concrete designs are still in accordance with the actual requirements, taking account of the change in properties of the constituent materials and the results of conformity testing on the concrete compositions.

9.6 Personnel, equipment and installation

9.6.1 Personnel

Knowledge, training and experience of personnel involved in production and production control shall be appropriate to the type of concrete, e.g. high strength concrete, light-weight concrete.

Appropriate records of the training and experience of the personnel involved in production and production control shall be maintained.

NOTE In some countries, there are special requirements regarding the level of knowledge, training and experience for the different tasks.

9.6.2 Equipment and installation

9.6.2.1 Storage of materials

Constituent materials shall be stored and handled so that their properties do not change significantly, e. g. by action of climate, intermingling or contamination, and that the conformity with the respective standard is maintained.

Storage compartments shall be clearly marked in order to avoid errors in use of the constituent materials.

Special instructions from the suppliers of the constituent materials shall be taken into account.

Facilities shall be provided to enable representative samples to be taken e.g. from stockpiles, silos and bins.

9.6.2.2 Batching equipment

The performance of the batching equipment shall be such that under practical conditions of operation the tolerances stated in 9.7 can be obtained and maintained.

After 2003-01-01, the accuracy of the weighing equipment shall conform to the accuracy requirements given in Directive 90/384/EEC, measured in accordance with EN 45501:1992, for at least Class (IIII) for cement, aggregates, water, admixtures and additions. The number of verification scale intervals (n) of the weighing equipment shall be:

— for admixtures, at least 1 000;

— for cement, aggregates, water and additions, at least 500.

NOTE For further information see Annex G (informative).

The accuracy of the volumetric measuring equipment shall conform to the accuracy requirements in OIML R 117.

Notwithstanding the requirements given above, existing batching equipment which does not conform to the requirements of this clause may be used until 2003-01-01, if the equipment conforms to the provisions valid in the place of production at the date of publication of this standard.

9.6.2.3 Mixers

The mixers shall be capable of achieving a uniform distribution of the constituent materials, and a uniform consistence of the concrete within the mixing time and at the mixing capacity.

Truck mixers and agitating equipment shall be so equipped as to enable the concrete to be delivered in a homogeneous state. In addition, the truck mixers shall be provided with suitable measuring and dispensing equipment, if water or admixtures are to be added on the site under the responsibility of the producer.

9.6.2.4 Testing equipment

All necessary facilities, equipment and instructions for its proper use shall be available when required for inspections and tests on equipment, constituent materials and concrete.

Relevant test equipment shall be in calibration at the time of testing and the producer shall operate a calibration programme.

9.7 Batching of constituent materials

A documented batching instruction giving details of the type and quantity of the constituent materials shall be available at the place of batching of the concrete.

The tolerance of batching constituent materials shall not exceed the limits given in Table 21 for all quantities of concrete of 1 m^3 or more. Where a number of batches is mixed or re-mixed in a truck mixer, the tolerances in Table 21 apply to the load.

Table 21 — Tolerances for the batching process of constituent material

Constituent material	Tolerance
Cement Water Total aggregates Additions used at > 5 % by mass of cement	±3 % of required quantity
Admixtures and additions used at ≤ 5 % by mass of cement	±5 % of required quantity
NOTE The tolerance is the difference between the target value and the measured value.	

Cements, aggregates and additions in the form of powders shall be batched by mass; other methods are permitted if the required batching tolerance can be achieved and this is documented.

The mixing water, light-weight aggregates, admixtures and liquid additions may be batched by mass or by volume.

9.8 Mixing of concrete

Mixing of the constituent materials shall be carried out in a mixer conforming to 9.6.2.3 and be continued until the concrete is of uniform appearance.

Mixers shall not be loaded in excess of their rated mixing capacity.

Admixtures, where used, shall be added during the main mixing process, except for high range water reducing admixtures or water reducing admixtures that may be added after the main mixing process. In the latter case, the concrete shall be re-mixed until the admixture has been completely dispersed throughout the batch or load and has become fully effective.

NOTE In a truck mixer, the duration of re-mixing after the main mixing process should not be less than 1 min/m^3 and not less than 5 minutes after adding the admixture.

For light-weight concrete batched with unsaturated aggregates, the period from initial mixing to the end of final-mixing (e.g. re-mixing in a truck mixer) shall be prolonged till the water absorption of the aggregates and subsequent evacuation of air from the light-weight aggregates does not have any significant negative impact on the hardened concrete properties.

The composition of the fresh concrete shall not be altered after leaving the mixer.

9.9 Production control procedures

The constituent materials, equipment, production procedures and concrete shall be controlled with regard to their conformity with the specifications and the requirements of this standard. The control shall be such that significant changes that influence the properties are detected and appropriate corrective action taken.

The types and frequency of inspections/tests for constituent materials shall be as given in Table 22.

NOTE This table is based on the assumption that there is adequate production control by the producer of the constituent materials at the places where the materials are produced and that the constituent materials are delivered with a declaration or a certificate of conformity with the relevant specification. If not, the producer of the concrete should check the conformity of the materials to the relevant standards.

The control of equipment shall ensure that the storage facilities, the weighing and gauging equipment, the mixer and control apparatus (e.g. the measuring of water content of the aggregates) are in good working condition and that they conform to the requirements of this standard. Frequency of inspections and tests for equipment (where used) are given in Table 23.

Plant, equipment and transport facilities shall be subject to a planned maintenance system and shall be maintained in efficient working condition so that the properties and the quantity of concrete are not adversely affected.

The properties of designed concrete shall be controlled to the specified requirements as given in Table 24.

The proportions of prescribed concrete, its consistence and temperature, where specified, shall be controlled to the specified requirements as given in Table 24 (lines 2 to 4, 6, 7 and 9 to 14).

The control shall include production, transport to the point of delivery and delivery.

For some concretes, additional requirements for production control may be necessary. For the production of high strength concrete, special knowledge and experience are required. These are not defined in the standard. Annex H gives some guidance. If the contract has defined special requirements for the concrete, the production control shall include appropriate actions in addition to those in Tables 22 to 24.

The actions foreseen in Tables 22 to 24, in special cases, may be adapted to the conditions of the specific production place and be replaced by actions which provide an equivalent level of control.

Table 22 — Control of constituent materials

	Constituent material	Inspection / test	Purpose	Minimum frequency
1	Cements[a]	Inspection of delivery ticket [d] prior to discharge	To ascertain if the consignment is as ordered and from the correct source	Each delivery
2	Aggregates	Inspection of delivery ticket[b] [d] prior to discharge	To ascertain if the consignment is as ordered and from the correct source	Each delivery
3		Inspection of the aggregate prior to discharge	For comparison with normal appearance with respect to the grading, shape and impurities	Each delivery Where delivery is by belt conveyor, periodically depending on local or delivery conditions
4		Test by sieve analysis according to EN 933-1	To assess compliance with standard or other agreed grading	First delivery from new source where this information is not available from the aggregate supplier In case of doubt following visual inspection Periodically depending on local or delivery conditions[e]
5		Test for impurities	To assess the presence and quantity of impurities	First delivery from new source where this information is not available from the aggregate supplier In case of doubt following visual inspection Periodically depending on local or delivery conditions[e]

Table 22 — Control of constituent materials *(continued)*

	Constituent material	Inspection / test	Purpose	Minimum frequency
6	Aggregates	Test for water absorption to EN 1097-6	To assess the effective water content of concrete, see 5.4.2	First delivery from new source where this information is not available from the aggregate supplier. In case of doubt.
7	Additional control for light-weight or heavy-weight aggregates	Test according to EN 1097-3	To measure the loose bulk density	First delivery from new source where this information is not available from the aggregate supplier. In case of doubt following visual inspection. Periodically depending on local or delivery conditions[e].
8	Admixtures[c]	Inspection of delivery ticket and label on container[d] prior to discharge	To ascertain if the consignment is as ordered and properly marked	Each delivery.
9		Tests for identification according to EN 934-2, e.g. density, infrared	For comparison with manufacturer's stated data	In case of doubt.
10	Additions[c] bulk powder	Inspection of delivery ticket[d] prior to discharge	To ascertain if the consignment is as ordered and from the correct source	Each delivery.
11		Test of loss of ignition of fly ash	To identify changes in carbon content which may effect air-entrained concrete	Each delivery to be used for air-entrained concrete where this information is not available from the supplier.
12	Additions in suspension[c]	Inspection of delivery ticket[d] prior to discharge	To ascertain if the consignment is as ordered and from the correct source	Each delivery.
13		Test for density	To ascertain uniformity	Each delivery and periodically during production of concrete.
14	Water	Test to prEN 1008:1997	To ascertain that the water is free from harmful constituents if the water is not potable.	Where a new non-potable source is used for first time. In case of doubt.

[a] It is recommended that samples are taken once per week from each cement type and stored for testing in case of doubt.

[b] The delivery ticket or the product data sheet shall also contain information on the maximum chloride content and should identify classification with respect to alkali silica reaction in accordance with the provisions valid in the place of use of the concrete.

[c] It is recommended that samples are taken at each delivery and stored.

[d] The delivery ticket shall contain or be accompanied by a declaration or certificate of conformity as required in the relevant standard or specification.

[e] This is not necessary where the production control for the aggregate is certified.

Table 23 — Control of equipment

	Equipment	Inspection/test	Purpose	Minimum frequency
1	Stockpiles, bins, etc.	Visual inspection	To ascertain conformity with the requirements	Once per week
2	Weighing equipment	Visual inspection of the performance	To ascertain that the weighing equipment is in a clean condition and functions correctly	Daily
3		Test of weighing accuracy	To ascertain the accuracy according to 9.6.2.2	On installation. Periodically[a] depending on national provisions. In case of doubt.
4	Admixtures dispenser (including those mounted on truck mixers)	Visual inspection of performance	To ascertain that the measuring equipment is in a clean condition and functions correctly	First use of the day for each admixture.
5		Test of accuracy	To avoid inaccurate dispensing	On installation. Periodically[a] after installation. In case of doubt.
6	Water meter	Test of measuring accuracy	To ascertain accuracy according to 9.6.2.2	On installation. Periodically [a] after installation. In case of doubt.
7	Equipment for continuous measurement of water content of fine aggregates	Comparison of the actual amount with the reading of the meter	To ascertain accuracy	On installation. Periodically [a] after installation. In case of doubt.
8	Batching system	Visual inspection	To ascertain that the batching equipment is functioning correctly	Daily
9		Comparison (by a suitable method depending on the batching system) of the actual mass of the constituents in the batch with the target mass and in the case of automatic batch recording with the recorded mass	To ascertain batching accuracy according to Table 21	On installation. In case of doubt. Periodically [a] after installation.
10	Testing apparatus	Calibration according to relevant national or EN Standards	To check the conformity	Periodically [a]. For strength testing apparatus, at least once per year.
11	Mixers (including truck mixers)	Visual inspection	To check the wear of the mixing equipment	Periodically [a].

[a] The frequency depends on the kind of equipment, its sensitivity in use and the production conditions of the plant.

Table 24 — Control of production procedures and of concrete properties

	Type of test	Inspection/test	Purpose	Minimum frequency
1	Properties of designed concrete	Initial test (see Annex A)	To provide proof that specified properties are met by the proposed design with an adequate margin	Before using a new concrete composition.
2	Water content of fine aggregates	Continuous measuring system, drying test or equivalent	To determine the dry mass of aggregate and the water to be added	If not continual, daily, depending on local and weather conditions more or less frequent tests may be required.
3	Water content of coarse aggregates	Drying test or equivalent	To determine the dry mass of aggregate and the water to be added	Depending on local and weather conditions.
4	Water content of fresh concrete	Check of the quantity of water added[a]	To provide data for the water/cement ratio	Every batch
5	Chloride content of concrete	Initial determination by calculation	To ensure that the maximum chloride content is not exceeded	When performing initial test. In case of an increase in the chloride content of the constituents.
6	Consistence	Visual inspection	For comparison with normal appearance	Each batch
7		Consistence test according to EN 12350-2, -3, -4 *or* -5	To assess the achievement of the specified values of consistence and to check possible changes of water content	Where consistence is specified, as Table 13 for compressive strength. When testing air content. In case of doubt following visual inspections.
8	Density of fresh concrete	Density test according to EN 12350-6	For light-weight and heavy-weight concrete for supervision of batching and density control	Daily
9	Cement content of fresh concrete	Check the mass of cement batched[a]	To check the cement content and to provide data for the water/cement ratio	Every batch
10	Additions content of fresh concrete	Check the mass of additions batched[a]	To check the additions content and to provide data for the w/c ratio (see 5.4.2)	Every batch
11	Admixture content of fresh concrete	Check the mass or volume of admixture batched[a]	To check the admixture content	Every batch
12	Water/cement ratio of fresh concrete	By calculation or by test method, see 5.4.2	To assess the achievement of the specified water/cement ratio	Daily, where specified
13	Air content of fresh concrete where specified	Test according to EN 12350-7 for normal-weight and heavy-weight concrete ASTM C 173 for light-weight concrete	To assess the achievement of the specified content of entrained air	For concretes containing entrained air: first batch or load of each production day until values stabilize.
14	Temperature of fresh concrete	Measure temperature	To assess the achievement of the minimum temperature of 5 °C or specified limit	In case of doubt. Where temperature is specified: — periodically, dependent on the situation; — each batch or load where the concrete temperature is close to the limit.
15	Density of hardened light-weight or heavy-weight concrete	Test according to EN 12390-7[b]	To assess the achievement of the specified density	Where density is specified, as frequently as compressive strength test.

Table 24 — Control of production procedures and of concrete properties *(continued)*

	Type of test	Inspection/test	Purpose	Minimum frequency
16	Compressive strength test on moulded concrete specimen	Test according to prEN 12390-3:1999	To assess the achievement of the specified strength	Where compressive strength is specified, as frequently as for conformity control, see 8.1 and 8.2.1.

[a] Where recording equipment is not used and the batching tolerances for the batch or load are exceeded, record the batched quantity in the production record.

[b] May also be tested in saturated conditions, where a safe relationship to oven-dry density is established.

10 Evaluation of conformity

10.1 General

The producer is responsible for the evaluation of conformity for specified requirements of the concrete. For this purpose, the producer shall carry out the following tasks:

a) initial tests, when required (see 9.5 and Annex A);

b) production control (see Clause 9), including conformity control (see Clause 8);

Whether approved inspection and certification bodies are recommended to inspect the production control and certify its conformity depends on the level of performance requirements for the concrete, its intended use, the kind of production and the margin of safety in the concrete composition.

In general, the inspection and certification of the production control by approved inspection and certification bodies is recommended. This is not considered to be necessary for standardized prescribed concrete with a high margin of safety in the composition (see Annex A.5), limited intended use and low concrete strength class (see 6.4).

For precast concrete products, the requirements and provisions for the evaluation of conformity are given in the relevant technical specifications (product standards and technical approvals).

10.2 Assessment, surveillance and certification of production control

Where it is required either in a contract or by provisions valid in the place of use of the concrete, that the producer's production control shall be assessed and surveyed by an approved inspection body and then certified by an approved certification body, the provisions for assessment, surveillance and certification given in Annex C apply.

11 Designation for designed concrete

Where the essential characteristics of designed concrete are to be given in an abbreviated form, the following format shall be applied:

— reference to this European Standard: EN 206-1;

— compressive strength class: compressive strength class as defined in Table 7 or 8, e.g. C25/30;

— for limiting values according to the exposure class: the class designation of Table 1, followed by the abbreviation of the country name[1)], that issued the provisions for the limiting values, concrete composition and concrete properties or other set of requirements, e.g. XD2(F) where the French provisions apply;

— maximum chloride content: the class defined in Table 10, e.g. Cl 0,20;

— maximum nominal upper aggregate size: the value D_{max} as defined in 4.2.2, e.g. D_{max} 22;

— density: the class designations as given in Table 9 or the target value, e.g. D1,8;

— consistence: by class as defined in 4.2.1 or by a target value and method.

1) In accordance with the internationally recognized car plate code. To the abbreviation of the country name, further information concerning the provisions may be added.

Annex A
(normative)

Initial test

A.1 General

This annex provides details of initial testing as indicated in 5.2.1, 5.2.5.1, 6.1 and 9.5.

The initial test shall establish a concrete that satisfies all specified requirements for fresh and hardened concrete. Where the producer or specifier can demonstrate an adequate design, based on data from previous tests or long-term experience, this may be considered as an alternative to initial tests.

A.2 Party responsible for initial tests

Initial tests shall be the responsibility of the producer for designed concrete, the specifier for prescribed concrete and the standardization body for standardized prescribed concrete.

A.3 Frequency of initial tests

Initial tests shall be performed before using a new concrete or concrete family.

Initial tests shall be repeated if there has been a significant change either in the constituent materials or in the specified requirements on which the previous tests were based.

A.4 Test conditions

In general, initial tests shall be carried out on fresh concrete with a temperature of 15 °C to 22 °C.

NOTE If concreting on the site will be done under widely divergent temperature conditions, or if heat treatment is applied, the producer should be informed about this, so that he can consider the concerning effects on the properties of the concrete and the need for any additional tests.

For the initial test of a single concrete, at least three specimens from each of three batches shall be tested. Where the initial test is for a concrete family, the number of concretes to be sampled shall encompass the composition range of the family. In this case, the number of batches per concrete may be reduced to one.

The strength of a batch or load shall be taken to be the average of the test results. The result of the initial test on the concrete is the average strength of the batches or loads.

The time between mixing and consistence testing, and the results shall be recorded.

A significantly higher number of tests is necessary for prescribing the composition of a standardized prescribed concrete to encompass all the permitted constituent materials, which are foreseen to be used on a national level. The results of the initial tests shall be documented at the responsible standard organization.

A.5 Criteria for adoption of initial tests

For assessing the properties of concrete, in particular those of fresh concrete, the differences between the type of mixer and mixing procedure applied during the initial test and those applied during actual production shall be taken into account.

The compressive strength of the concrete with the composition to be adopted for the actual case shall exceed the values f_{ck} of Table 7 or 8 by an adequate margin. This margin shall be at least that needed to satisfy the conformity criteria given in 8.2.1. The margin should be about twice the expected standard deviation, that means at least a margin of 6 N/mm^2 to 12 N/mm^2 depending on the production facilities, the constituent materials and the available background information about the variation.

The criterion for adoption of initial tests for standardized prescribed concrete is:

$f_{cm} \geq f_{ck} + 12$

The consistence of the concrete shall be within the limits of the consistence class, at the time at which the concrete is likely to be placed or in the case of ready mixed concrete, delivered.

For other properties that are specified, the concrete shall meet the specified values with an appropriate margin.

Annex B
(normative)

Identity testing for compressive strength

B.1 General

This annex provides details for identity testing as indicated in 8.2.1.1.

Identity testing indicates whether the defined volume of concrete in question belongs to the same population as that verified as conforming with the characteristic strength via conformity assessment by the producer.

B.2 Sampling and testing plan

Where identity testing is to be performed, the particular volume of concrete shall be defined, e.g.:

— single batch or load where there is doubt as to the quality;
— the concrete supplied for each storey of a building or group of beams/slabs or columns/walls of a storey of a building or comparable parts of other structures;
— the concrete delivered to a site within one week, but not more than 400 m^3.

The number of samples to be taken from a particular volume of concrete shall be defined.

Samples shall be taken from different batches or loads in accordance with EN 12350-1.

Test specimens shall be prepared and cured in accordance with EN 12390-2. The compressive strength of the specimens shall be determined in accordance with prEN 12390-3:1999. The test result shall be that obtained from the average of the results of two or more specimens made from one sample for testing at the same age. Where the range of the test values is more than 15 % of the mean, the results shall be disregarded unless an investigation reveals an acceptable reason to justify disregarding an individual test value.

B.3 Identity criteria for compressive strength

B.3.1 Concrete under production control certification

Identity of concrete is assessed for each individual strength test result and the average of n non-overlapping discrete results as identified in Table B1.

Concrete is deemed to come from a conforming population if both the criteria in Table B.1 are satisfied for n results derived from strength tests on samples taken from the defined volume of concrete.

Table B.1 — Identity criteria for compressive strength

Number n of test results for compressive strength from the defined volume of concrete	Criterion 1	Criterion 2
	Mean of n results (f_{cm}) N/mm²	Any individual test result (f_{ci}) N/mm²
1	Not applicable	$\geq f_{ck} - 4$
2 - 4	$\geq f_{ck} + 1$	$\geq f_{ck} - 4$
5 - 6	$\geq f_{ck} + 2$	$\geq f_{ck} - 4$

NOTE The identity criteria of Table B.1 give a probability of 1 % that a conforming concrete volume is rejected.

B.3.2 Concrete not under production control certification

From the defined volume of concrete, at least 3 samples shall be taken for testing.

The concrete is deemed to come from a conforming population if the conformity criteria in 8.2.1.3 and Table 14 for initial production are satisfied.

Annex C
(normative)

Provisions for assessment, surveillance and certification of production control

C.1 General

Where required for the production control (see Clause 9), the provisions for assessment, surveillance and certification of production control by an approved body are given in this annex.

C.2 Tasks for the inspection body

C.2.1 Initial assessment of the production control

An initial inspection of the concrete plant and its production control shall be performed by the approved inspection body. The initial inspection is for the purpose of determining whether the prerequisites, in terms of staff and equipment for orderly production and for the corresponding production control, appear to be suitable.

The inspection body shall at least check:

— the producer's production control manual and assess the provisions of it and in particular whether it conforms with the requirements for production control in Clause 9 and whether it takes account of the requirements of this standard;
— the availability of current documents essential for plant inspections at the relevant places and if these are available to the relevant persons;
— if all necessary facilities and equipment are available to carry out the necessary inspections and tests on equipment, constituent materials and concrete;
— the knowledge, training and experience of the staff for production and production control;
— if initial testing is performed according to Annex A of this standard and if this is reported in an adequate manner.

If indirect testing is performed or if conformity for strength is based on the transposed results of the family concept, the producer shall prove the correlation or safe relationship between the direct and indirect testing to the satisfaction of the inspection body.

To provide confidence in the results of the production control, the inspection body shall perform spot tests in parallel to those of the producer's. Such testing may be replaced by an in-depth surveillance of the producer's data and control system where the producer's testing laboratory is accredited and under the surveillance of an accreditation body.

All the relevant facts from the initial inspection, especially the equipment at the production place, the production control system and the assessment of the system, shall be documented in an assessment report.

When a production unit has passed the initial inspection to the satisfaction of the inspection body, the inspection body shall issue an assessment report that the production control conforms to Clause 9 of this standard. This report shall be passed to the producer and to the approved certification body.

NOTE On the basis of this report the approved certification body will decide on the certification of the production control (see C.3.1).

C.2.2 Continuous surveillance of the production control

C.2.2.1 Routine inspection

The principal objective of the routine inspection by the inspection body is to check whether the prerequisites for production and agreed production control are being maintained. For this purpose, the assessment report of the initial inspection is used as a statement of the agreed production control.

The producer is responsible for the maintenance of the production control system. When significant changes are made at the facilities at the production place, to the production control system or to the production control manual, the producer shall notify the changes to the inspection body which may request a re-inspection.

During the routine inspection, the inspection body shall at least assess:

- the production, sampling and testing procedures;
- the recorded data;
- the test results obtained for production control during the inspection period;
- that the required tests or procedures have been carried out with appropriate frequency;
- that the production equipment has been checked and maintained as scheduled;
- that the test equipment has been maintained and calibrated as scheduled;
- the actions taken with respect to any non-conformity;
- the delivery tickets and the declarations of conformity, where relevant.

To provide confidence in the sampling and testing of the producer's production control the inspection body shall, during the routine inspection, take spot samples from the running production for testing. Sampling for this purpose shall not be announced in advance. The inspection body shall determine the appropriate frequency for each production unit, in which testing on the concrete should be conducted, taking account of the individual circumstances. Such testing may under special individual circumstances be replaced by an in-depth surveillance of the producer's data and control system when the producer's testing laboratory is accredited and under the surveillance of the accreditation body.

Designed concretes shall be tested for the specified properties, e.g. strength, consistence. For prescribed concrete, testing shall cover consistence and composition only.

Comparison shall be made between the producer's routine test results and the results of testing by the inspection body.

The inspection body shall periodically examine the safe relationship between the direct and indirect testing and the relationships between the members of a concrete family.

The results of the routine inspection shall be documented in a report to be passed to the producer and the certification body.

The routine inspections shall be performed, at least, twice a year, except where the verification or the certification scheme defines conditions for decreasing or increasing that frequency.

C.2.2.2 Extraordinary inspections

An extraordinary inspection is necessary:

- if severe discrepancies are detected during a routine inspection (re-inspection);
- when there has been no production for a period of more than six months;
- where requested by the producer, e.g. because of changes in the production conditions;
- if requested by the certification body, giving due justification.

The scope, type and timing of the extraordinary inspection depends on the particular situation.

C.3 Tasks for the certification body

C.3.1 Certification of production control

The certification body shall certify the production control on the basis of a report from the inspection body, that states the production unit has passed the initial assessment of the production control to the satisfaction of the inspection body.

The certification body shall decide on the further validity of the certificate on the basis of the reports of the continuous surveillance of the production control.

C.3.2 Measures in case of non-conformity

Where the inspection body identifies non-conformity with the specification or where defects have been revealed in the production process or in the production control on which the producer has not reacted properly in due time (see 8.4), the certification body shall request the producer to rectify the defects within an appropriately short period. The actions of the producer shall be verified by the inspection body.

If appropriate, an extraordinary inspection and additional tests shall be arranged in the case of non-conformity with:

— strength;

— water/cement ratio;

— basic limits on the composition;

— density, where specified for designed light-weight and heavy-weight concrete;

— specified composition in the case of prescribed concrete.

If the results of the extraordinary inspection are not satisfactory or if the additional tests failed the set criteria, the certification body shall suspend or withdraw the certificate of conformity of the production control without undue delay.

NOTE After the suspension or the withdrawal of the certificate of the conformity of the production control, the producer is no longer permitted to refer to the certificate.

In case of other faults, the certification body may consider an extraordinary inspection unnecessary and may accept documentary evidence that the fault has been rectified. Such evidence shall be confirmed during the next routine inspection.

Annex D
(informative)

Bibliography

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

EN 12390-4, *Testing hardened concrete — Part 4: Compressive strength — Specification for compression testing machines*

EN 12390-5, *Testing hardened concrete — Part 5: Flexural strength of test specimens*

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

EN 12504-1, *Testing concrete in structures — Part 1: Cored specimens — Taking, examining and testing in compression*

EN 12504-2, *Testing concrete in structures — Part 2: Non-destructive testing — Determination of rebound number*

prEN 12504-3:1999, *Testing concrete in structures — Part 3: Determination of pull-out force*

prEN 12504-4:1998, *Testing concrete in structures — Part 4: Determination of ultrasonic pulse velocity*

ENV 13670-1, *Execution of concrete structures — Part 1: Common rules*

prEN 13791:1999, *Assessment of concrete compressive strength in structures or in structural elements*

EN ISO 9001, *Quality systems — Model of quality assurance in design/development, production, installation and servicing,* [ISO 9001:1994]

CR 1901, *Regional specifications for the avoidance of damaging alkali-silica reactions in concrete*

CR 13901, *The use of the concept of concrete families for production and conformity control of concrete*

CR 13902, *Determination of water/cement ratio of fresh concrete*

CEB Bulletin of Information 197 — FIP, High strength concrete — State of the art report; SR 90/1-1990

Annex E
(informative)

Guidance on the application of the equivalent performance concept of concrete properties

This annex provides details of the equivalent concrete performance concept in 5.2.5.1 and 5.2.5.3.

Testing should show that the performance of the concrete containing the addition should be at least equivalent to that of the reference concrete.

The reference concrete should:

— contain a cement conforming to EN 197-1 of the type and having the constituents corresponding to the combination of cement and addition;
— conform to the requirements of 5.3.2 for the relevant exposure class.

Where there is no corresponding cement available, CEM I cement should be used.

The test program should cover all tests required to demonstrate that the concrete containing the addition performs in an equivalent manner compared with the reference concrete in respect to the specific effects resulting from the environmental action of the specific exposure class.

Testing should be carried out at the same time and in the same laboratory that should be experienced and accredited for the relevant tests. The test result should provide a similar degree of reliability in the performance of the concrete as concrete containing cement conforming to EN 197-1 and conforming to the requirements of 5.3.2 for the relevant exposure class.

The range of compositions for which this method applies should be limited to:

— the total amount of addition, including that already contained as a constituent in the cement, should be within the limits given EN 197-1 for a corresponding permitted type of cement;
— the sum of cement and addition should be at least equal to the cement content requirement in 5.3.2 for the relevant exposure class;
— the water/(cement + addition) ratio should not be greater than the requirement in 5.3.2 for the maximum water/cement ratio for the relevant exposure class.

Annex F
(informative)

Recommendation for limiting values of concrete composition

This annex provides recommendations for the choice of the limiting values of concrete composition and properties in relation to exposure classes according to 5.3.2.

The values in Table F.1 are based on the assumption of an intended working life of the structure of 50 years.

The values in Table F.1 refer to the use of cement type CEM I conforming to EN 197-1 and aggregate with maximum nominal upper size in the range of 20 mm to 32 mm.

The minimum strength classes were derived from the relationship between water/cement ratio and the strength class of concrete made with cement of strength Class 32,5.

The limiting values for the maximum water/cement ratio and the minimum cement content apply in all cases, whilst the requirements for concrete strength class may be additionally specified.

Table F.1 — Recommended limiting values for composition and properties of concrete

	Exposure classes																	
	No risk of corrosion or attack	Carbonation-induced corrosion				Chloride-induced corrosion						Freeze/thaw attack				Aggressive chemical environments		
						Sea water			Chloride other than from sea water									
	X0	XC 1	XC 2	XC 3	XC 4	XS 1	XS 2	XS 3	XD 1	XD 2	XD 3	XF 1	XF 2	XF 3	XF 4	XA 1	XA 2	XA 3
Maximum w/c	—	0,65	0,60	0,55	0,50	0,50	0,45	0,45	0,55	0,55	0,45	0,55	0,55	0,50	0,45	0,55	0,50	0,45
Minimum strength class	C12/15	C20/25	C25/30	C30/37	C30/37	C30/37	C35/45	C35/45	C30/37	C30/37	C35/45	C30/37	C25/30	C30/37	C30/37	C30/37	C30/37	C35/45
Minimum cement content (kg/m^3)	—	260	280	280	300	300	320	340	300	300	320	300	300	320	340	300	320	360
Minimum air content (%)	—	—	—	—	—	—	—	—	—	—	—	—	4,0[a]	4,0[a]	4,0[a]	—	—	—
Other requirements												Aggregate in accordance with prEN 12620:2000 with sufficient freeze/thaw resistance					Sulfate-resisting cement[b]	

[a] Where the concrete is not air entrained, the performance of concrete should be tested according to an appropriate test method in comparison with a concrete for which freeze/thaw resistance for the relevant exposure class is proven.

[b] When SO_4^{2-} leads to exposure Classes XA2 and XA3, it is essential to use sulfate-resisting cement. Where cement is classified with respect to sulfate resistance, moderate or high sulfate-resisting cement should be used in exposure Class XA2 (and in exposure Class XA1 when applicable) and high sulfate-resisting cement should be used in exposure Class XA3.

Annex G
(informative)

Accuracy requirements for batching equipment

G.1 General

This annex summarizes the application of EN 45501:1992 as required in 9.6.2.2 of this standard.

In line with the CEN rules, EN 45501:1992 should have been implemented as the national standard in all CEN member countries at the latest by 1993, together with the withdrawal of the existing conflicting national standards at the latest by December, 1995.

EN 45501:1992 specifies the metrological and technical requirements for non-automatic weighing instruments. A European Standard for automatic weighing equipment is not yet available. However, it is expected that it will refer to EN 45501:1992. Therefore, EN 206-1 requires an application of EN 45501:1992 for both non-automatic and automatic weighing equipment. Non-automatic weighing instruments require the intervention of an operator during the weighing process e.g. to deposit in, or remove from the receptor (hopper) the load to be measured. The instrument enables direct observation of the weighing results either on display or as a print-out.

G.2 Accuracy classes

In EN 45501:1992, accuracy is classified into 4 classes:

Class (I), Special accuracy

Class (II), High accuracy

Class (III), Medium accuracy

Class (IIII), Ordinary accuracy

For concrete production, at least Class (IIII) for weighing cement, aggregates, water, admixtures and additions has been selected for this standard.

G.3 Classification of instruments

The verification scale interval, the number of verification scale intervals and the minimum capacity for Class (IIII) are given in the following table. The verification scale interval for graduated instruments without auxiliary indicating devices is equal to the actual scale interval. Where instruments have auxiliary indicating devices or are non-graduated, the verification scale interval is selected by the manufacturer in accordance with guidance in EN 45501:1992.

Table G.1 — (Extract from Table 3 of EN 45501:1992)

Accuracy class	Verification scale interval (e)	Number (n) of verification scale intervals (e) $n = \frac{\text{max. capacity}}{e}$	Minimum capacity of equipment to avoid excessive error
Ordinary (IIII)	5 g ≤ e	100 ≤ n ≤ 1 000	10 e

The number (n) of verification scale intervals (e) should be:

— for admixtures, at least 1 000;
— for cement, aggregate, water and additions, at least 500 (see 9.6.2.2).

EXAMPLE A weighing equipment for cement has a capacity of 3 000 kg while the scale interval is 5 kg.
The number (n) of verification scale intervals (e) is (n) = 3 000/5 = 600 which is within the permitted range of column 3 of Table G.1 and ≥ 500.

Maximum permissible errors:
A distinction is made between the maximum permissible errors at the initial verification after installation and in service as shown in Table G.2.

Table G.2 — (Extract from Table 6 of EN 45501:1992)

For loads (m) expressed in verification scale intervals (e)	Maximum permissible errors	
Class (IIII)	initial verification	in service
$0 \leq m \leq 50\ e$	± 0,5 e	± 1,0 e
$50\ e < m \leq 200\ e$	± 1,0 e	± 2,0 e
$200\ e < m \leq 1\ 000\ e$	± 1,5 e	± 3,0 e

G.4 Other Requirements in EN 45501:1992

Full details of the testing for verification are described in detail within the standard that also describes general technical requirements for the design and construction of suitable instruments.

Normative annexes of EN 45501:1992 give testing procedures for:

— non-automatic weighing instruments;
— additional tests for electronic instruments.

Annex H
(informative)

Additional provisions for high strength concrete

This annex gives some recommendations on provisions for production control additional to those given in Tables 22, 23 and 24 when high strength concrete is produced.

Numbers for the rows in the following Tables H.1, H.2 and H.3 are related to those in Tables 22, 23 and 24 respectively and replace or amend the equivalent requirements.

Table H.1 — Control of constituent materials

	Constituent material	Inspection / test	Purpose	Minimum frequency
4	Aggregates	Test by sieve analysis according to EN 933-1 or aggregate supplier information	To assess compliance with agreed grading	Each delivery, unless the aggregates are delivered with restricted tolerances and with a certificate of the production control.
9a	Admixtures[a]	Test for dry material content	For comparison with the declared value on the data sheet	Each delivery, unless the test data for this delivery are provided by the supplier. In case of doubt.
9b		Test for density	For comparison with nominal density	Each delivery
11	Additions bulk powder	Test of loss of ignition	To identify changes in carbon content that may effect the fresh concrete properties	Each delivery, unless the test data for this delivery are provided by the supplier.
[a] It is recommended that samples are taken from each delivery and stored.				

NOTE Additional information for production control for high strength concrete may be taken from the relevant literature, e.g. CEB Bulletin of Information 197 — FIP, High strength concrete — State of the art report; SR 90/1-1990.

Table H.2 — Control of equipment

	Equipment	Inspection/test	Purpose	Minimum frequency
1	Stockpiles, bins, etc.	Visual inspection	To ascertain conformity with the requirements	Daily
3a	Weighing equipment	Test of weighing accuracy	Confirmation of accuracy at single point	Weekly
5	Admixture dispensers (including those mounted on truck mixers)	Test of accuracy	To achieve accurate dispensing	On installation. Weekly after installation. In case of doubt.
6a	Water meter	Comparison of the measured value with the target value	To ascertain accuracy according to Clause 9.7	On installation. Weekly after installation. In case of doubt.
7	Equipment for continuous measurement of water content of fine aggregates	Comparison of the measured value with the reading of the meter	To ascertain accuracy	On installation. Weekly after installation. In case of doubt.
9	Batching system	Comparision (by a suitable method depending on the batching system) of the measured value of the constituents in the batch with the target value and in the case of automatic batch recording also with the recorded value.	To ascertain batching accuracy according to Table 21	On first installation. In case of doubt at subsequent installations. Monthly after installation.

Table H.3 — Control of production procedures and of concrete properties

	Type of test	Inspection/ test	Purpose	Minimum frequency
3	Water content of the coarse aggregates	Drying test or equivalent	To determine the mass of aggregates and the water to be added	Daily. Depending on local and weather conditions more or less frequent test may be required.
4	Added water content of fresh concrete	Record[a] of the quantity of water added	To provide data for the water/cement ratio	Every batch
9	Cement content of fresh concrete	Record[a] of the quantity of cement added	To check the cement content and to provide data for the water/cement ratio	Every batch
10	Additions content of the fresh concrete	Record[a] the quantity of additions added	To check the additions content	Every batch
[a] For production of high strength concrete automatic recording weighing equipment is recommended.				

Annex J
(informative)

Performance-related design methods with respect to durability

J.1 Introduction

This annex gives brief details of the approach and principles for a performance-related design method with respect to durability as referred to in 5.3.3.

J.2 *Definition*

The performance-related method considers each relevant deterioration mechanism, the working life of the element or structure, and the criteria that define the end of this working life, in a quantitative way.

Such a method may be based on satisfactory experience with local practices in local environments, on data from an established performance test method for the relevant mechanism, or on the use of proven predictive models.

J.3 Applications and general guidance

a) Some aggressive actions are best dealt with by a prescriptive approach, e.g. alkali-silica reaction, sulfate attack, or abrasion.

b) Performance-related design methods are more relevant to corrosion resistance and possibly, freeze-thaw resistance of concrete. This approach may be appropriate where:

- a working life significantly differing from 50 years is required;
- the structure is "special" requiring a lower probability of failure;
- the environmental actions are particularly aggressive, or are well defined;
- standards of workmanship are expected to be high;
- a management and maintenance strategy is to be introduced, perhaps with planned upgrading;
- significant populations of similar structures, or elements, are to be built;
- new or different constituent materials are to be used;
- method according to 5.3.2 has been used in design, but there has been a failure to conform.

c) In practice, the level of durability achieved depends on a combination of design, materials and execution.

d) The sensitivity of the design concept, the structural system, the shape of members and structural/architectural detailing are all significant design parameters for all methods of durability design.

e) Compatibility of materials, the construction method, the quality of workmanship, levels of control and quality assurance are significant parameters for all methods of durability design.

f) The required durability performance depends on the required working life, on the possible future use of the structure, on the particular protective measures, on the planned maintenance in service, and on the consequences of failure, in the particular local environment.

g) For any required level of performance, it is possible to derive alternative equivalent solutions from different combinations of design, material and construction factors.

h) The level of knowledge of the ambient and local micro-climate is important in establishing the reliability of performance-related design methods.

J.4 Performance-related methods with respect to durability

In applying the methods listed below, it is important to define in advance, at least the following:

— type of structure and its form;
— local environmental conditions;
— level of execution;
— required working life.

Some assumptions and judgements on these issues will usually be necessary to reduce the chosen method to a pragmatic and practical level.

The methods that may then be used include:

a) The refinement of the method according to 5.3.2, based on long-term experience of local materials and practices, and on detailed knowledge of the local environment.

b) Methods based on approved and proven tests that are representative of actual conditions and have approved performance criteria.

c) Methods based on analytical models that have been calibrated against test data representative of actual conditions in practice.

The concrete composition and the constituent materials should be closely defined to enable the level of performance to be maintained.

Annex K
(informative)

Concrete families

K.1 General

This annex provides details on the use of concrete families as indicated in 8.2.1.1.

K.2 Selection of the concrete family

When selecting the family for production and conformity control, the producer must achieve control over all the family members. Where there is little experience of using the concrete family concept, the following is recommended for a family:

— cement of one type, strength class and source;

— demonstrably similar aggregates and type I additions;

— concretes with or without a water reducing/plasticizing admixture;

— full range of consistence classes;

— concretes with a limited range of strength classes.

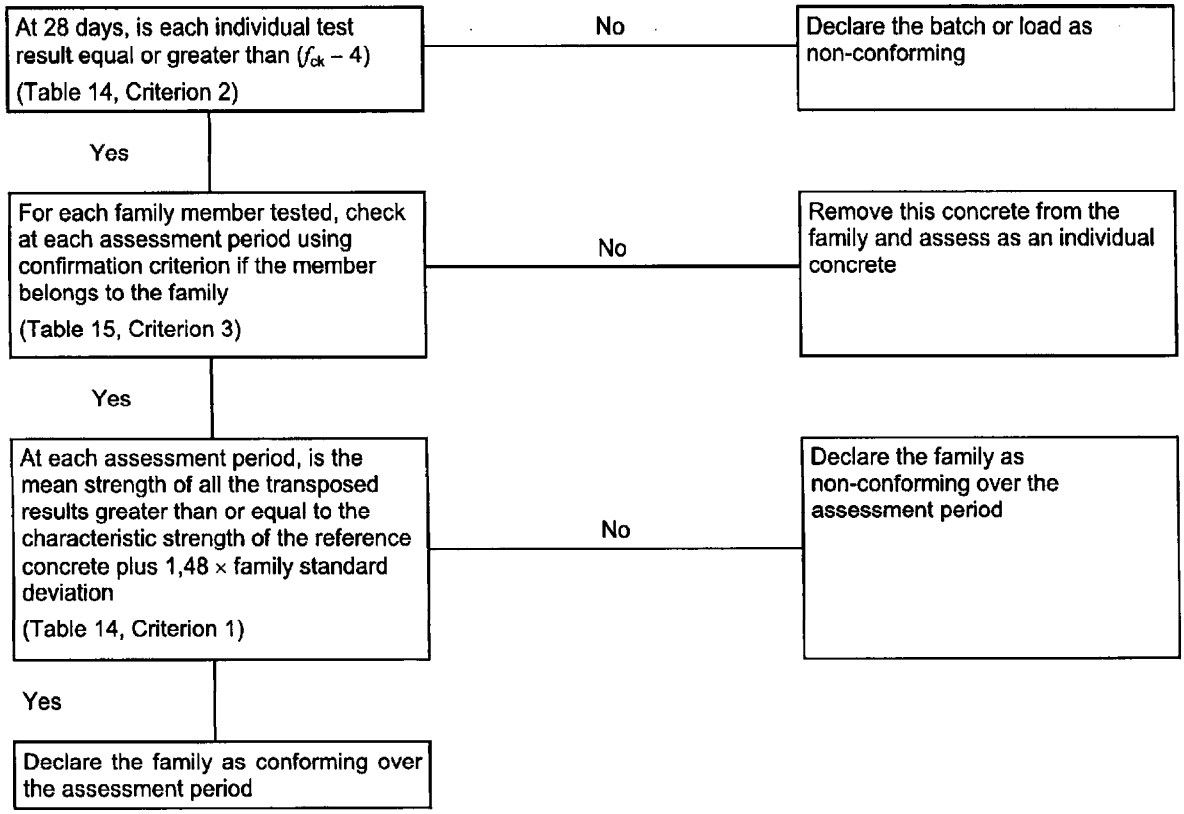
Concretes containing a type II addition, i.e. a pozzolanic or latent hydraulic addition, should be put into a separate family.

Concretes containing admixtures that may have an impact on compressive strength, e.g. high range water reducing/superplasticizing, accelerators, retarding or air entraining admixture should be treated as individual concretes or separate families.

To be demonstrably similar, aggregates should be from the same geological origin, be of the same type, e.g. crushed, and have a similar performance in concrete.

Before using the family concept or extending the families given above, the relationships should be tested on previous production data to prove that they give adequate and effective production and conformity control.

K.3 Flow chart for the assessment of membership and conformity of a concrete family



BSI — British Standards Institution

BSI is the independent national body responsible for preparing British Standards. It presents the UK view on standards in Europe and at the international level. It is incorporated by Royal Charter.

Revisions

British Standards are updated by amendment or revision. Users of British Standards should make sure that they possess the latest amendments or editions.

It is the constant aim of BSI to improve the quality of our products and services. We would be grateful if anyone finding an inaccuracy or ambiguity while using this British Standard would inform the Secretary of the technical committee responsible, the identity of which can be found on the inside front cover. Tel: 020 8996 9000. Fax: 020 8996 7400.

BSI offers members an individual updating service called PLUS which ensures that subscribers automatically receive the latest editions of standards.

Buying standards

Orders for all BSI, international and foreign standards publications should be addressed to Customer Services. Tel: 020 8996 9001. Fax: 020 8996 7001. Standards are also available from the BSI website at http://www.bsi-global.com.

In response to orders for international standards, it is BSI policy to supply the BSI implementation of those that have been published as British Standards, unless otherwise requested.

Information on standards

BSI provides a wide range of information on national, European and international standards through its Library and its Technical Help to Exporters Service. Various BSI electronic information services are also available which give details on all its products and services. Contact the Information Centre. Tel: 020 8996 7111. Fax: 020 8996 7048.

Subscribing members of BSI are kept up to date with standards developments and receive substantial discounts on the purchase price of standards. For details of these and other benefits contact Membership Administration. Tel: 020 8996 7002. Fax: 020 8996 7001. Further information about BSI is available on the BSI website at http://www.bsi-global.com.

Copyright

BSI
389 Chiswick High Road
London
W4 4AL