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Beton. Eigenschaften, Herstellung,
Verarbeitung und Gütenachweis

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EUROPEAN STANDARD
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ENV 206

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Descriptors: Concrete, composition, property, classification, characteristics, durability, specifications, delivery, production, implementation, quality control, conformity tests

English version

Concrete — Performance, production, placing and compliance criteria

Béton — Performances, production, mise en oeuvre et critères de conformité

Beton — Eigenschaften, Herstellung, Verarbeitung und Gütenachweis

This European Prestandard (ENV) was approved by CEN on 1989-09-19 as a prospective standard for provisional application. The period of validity of the ENV is limited initially to three years. After two years the members of CEN will be requested to submit their comments, particularly on the question whether the ENV can be converted into a European Standard (EN).

CEN members are required to announce the existence of this ENV in the same way as for an EN and to make the ENV available promptly at national level in an appropriate form. It is permissible to keep conflicting national standards in force (in parallel to the ENV) until the final decision about the possible conversion of the ENV into an EN is reached.

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CEN

European Committee for Standardization
Comité Européen de Normalisation
Europäisches Komitee für Normung

Central Secretariat: rue de Stassart 36, B-1050 Brussels

Ref. No. ENV 206:1990 E

Brief history

This European Prestandard was prepared by Technical Committees CEN/TC 94 "*Ready mixed concrete — Production and delivery*" and CEN/TC 104 "*Concrete — Performance, production, placing and compliance criteria*" with Belgium, Denmark, France, Germany, Ireland, Italy, Netherlands, Norway, Portugal, Spain, Sweden and United Kingdom as participating members and DIN assuming the Secretariat.

This prestandard was elaborated on the basis of the Draft European Standards prEN 199 *Ready mixed concrete — Production and delivery* and prEN 206 *Concrete — Performance, production, placing and compliance criteria*. The work on prEN 199 commenced in 1979 and was brought to a temporary end in 1981.

CEN/TC 94 agreed that prEN 199 was only concerned with specifications for production, delivery and quality control specific to ready-mixed concrete. As for those aspects which pertain to the building material concrete, it was assumed that these would be dealt with in another European Standard which was under discussion in CEN/TC 104. The work in CEN/TC 104 commenced in 1981 on the document prEN 206 which was finalized in 1984 and sent for preliminary voting in 1985.

At the preliminary voting on prEN 199 and prEN 206 neither draft gained the required majority for implementation as European Standards for technical reasons as well as for reasons concerning the immediate implementation of the documents as national standards in accordance with CEN rules. After careful consideration of the comments received, both Committees CEN/TC 94 and CEN/TC 104 decided at a joint meeting in 1986 to merge the drafts prEN 199 and prEN 206 into a single document and to give this future document the status of a European Prestandard (see "Status of the document") to meet the objections of several CEN members concerning its immediate implementation.

The document submitted as ENV 206 is the result of discussions at four joint meetings of the Committee CEN/TC 94 and CEN/TC 104, was prepared at several meetings of a Joint Working Group which have taken place since 1986, and is based on the papers prEN 199 and prEN 206 as well as on the comments received during preliminary voting, and especially at the last joint meeting of CEN/TC 94 and CEN/TC 104 in Milan in June 1988.

In accordance with CEN/CENELEC Common Rules, the following countries are bound to implement this European Prestandard: Austria, Belgium, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Luxembourg, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland and United Kingdom.

Status of the document

In the opinion of the Committees CEN/TC 94 and CEN/TC 104 the present document has the status of a European Prestandard (ENV). According to the common rules of CEN/CENELEC this means that the document has no obligatory character for the CEN members and does not have to be automatically implemented in their national standards.

One of the main objectives of this European Prestandard is to state provisions for the material concrete harmonizing and completing those contained in Eurocode 2 for the design and execution of concrete structures. Thus in Eurocode 2 and Eurocode 4 reference is made to ENV 206 concerning concrete technology. In those cases where the Eurocodes are used for structural design, the European Prestandard ENV 206 becomes automatically obligatory.

In the document provisions are expressed by the terms "shall" and "should". In cases where "shall" is used it means that the provisions are obligatory requirements. In cases where "should" is used it means that the provisions are to be followed in normal applications and if there are variations from the provisions they have to be justified; but the variations have to follow the provisions expressed by "shall" in any case.

Further procedure

According to the common rules of CEN/CENELEC, three years after the document has been adopted and published as a European Prestandard, it has to be examined in order to check its technical content and the possible alteration of its status into that of a European Standard (EN).

Another reason to choose the status of a European Prestandard was a certain number of technical questions remaining unclarified. In some cases a uniform European regulation could not yet be achieved and reference had to be made to national regulations. In other cases the reference documents were not available in their final form (for instance the European Standard specifications for cement, EN 197, and some other test standards). Possible modifications of these documents could also have an influence of ENV 206.

Agreement on other questions can only be considered to be preliminary and corresponding experience has still to be gained in the European field, as concerning for instance

— the requirements for durability;

— the provisions for quality control (e.g. statistical principles, conformity criteria, number of samples);

— extension of Table 8 to higher strength classes;

— strength classes for light-weight concrete;

— consideration of additions in the determination of the w/c ratio and the cement content;

— requirements for qualification of the personnel;

— differing provisions for the production of precast elements;

— examination of all reference ISO standards;

— identification of division of responsibility between purchaser and supplier;

— reconsideration of accuracy of weighing equipment;

— reconsideration of curing requirements.

The Technical Committees decided to continue to work on these items immediately after the publication of the European Prestandard ENV 206, i.e. within the three year period of validity mentioned above.

Contents

1 General

1.1 Object

This European Prestandard gives technical requirements for the constituent materials of concrete, the concrete composition, the properties of fresh and hardened concrete and their verification, also for the production of concrete, its transport, delivery, placing and curing and the quality control procedures.

Another purpose of this prestandard is to give the information on concrete as a material which is necessary for use with the relevant Eurocodes.

1.2 Field of application

The provisions of this prestandard are applicable to concrete mixed on site, ready mixed concrete or concrete produced in a factory. The prestandard is applicable to cast in situ or prefabricated structures and structural components for buildings and civil engineering structures where plain, reinforced or prestressed concrete is used. The prestandard is not applicable to certain precast concrete products such as masonry blocks, paving, pipes, nor for grout, etc.

Additional, or sometimes even different, requirements may be necessary

— for complex structures such as special viaducts, large dams, pressure vessels for nuclear power stations, offshore structures, and for roads;

— for using new constituent materials, special technologies (e.g. manufacturing processes) or innovating technologies in the building process.

In all cases the measures chosen shall be suitable and shall not conflict with the requirements for safety and durability of the structure.

This prestandard applies only to concrete having a closed structure made with normal-weight aggregate, so made and compacted as to retain no appreciable amount of entrapped air other than entrained air in accordance with **6.2.2**.

The provisions of this prestandard may, in principle, also be applied to heavy-weight concrete (see **3.8**) with natural aggregates and to light-weight concrete (see **3.7**) with artificial or natural aggregates as appropriate. In these cases, however, special considerations may be necessary in addition.

Besides the provisions of this prestandard other rules may be used for simple structures of less importance if they are covered by national regulations.

2 References

2.1 General

The term "normative" means that the requirements of the standards or parts of them, to which reference is made in the relevant clauses of ENV 206, are to be used exclusively.

Exceptionally, during the lifetime of ENV 206, nationally adopted test methods may be used, provided it is affirmed by the national standards body that the results achieved according to the national standards are equivalent to those achieved by relevant international standards.

The term "optional" in **2.3** means that other equivalent standards or rules may be agreed upon.

2.2 Normative references

EN 196-7, *Methods of testing cement — Part 7: Methods of taking and preparing samples of cement.*

EN 197-1, *Cement; Composition, specifications and conformity criteria — Part 1: Definitions and composition* [1].

EN 197-2, *Cement; Composition, specifications and conformity criteria — Part 2: Specifications*[1].

EN 197-3, *Cement; Composition, specifications and conformity criteria — Part 3: Conformity criteria* [1].

ISO 1920:1976, *Concrete tests — Dimensions, tolerances and applicability of test specimens*[2].

ISO 2736-1:1986, *Concrete tests — Making of test specimens — Part 1: Sampling of fresh concrete.*

ISO 2736-2:1986, *Concrete tests — Making of test specimens — Part 2: Making and curing of test specimens for strength tests*[2].

ISO 4012:1978, *Concrete — Determination of compressive strength of test specimens*[2].

ISO 4013:1978, *Concrete — Determination of flexural strength of test specimens*[2].

ISO 4103:1979, *Concrete — Classification of consistency.*

ISO 4108:1980, *Concrete — Determination of tensile splitting strength of test specimens.*

ISO 4848:1980, *Concrete — Determination of air content of freshly mixed concrete — Pressure method.*

ISO 7031, *Concrete, hardened — Determination of the depth of penetration of water under pressure*[2] [1].

ISO 9690, *Production and control of concrete. Classification of chemically aggressive environmental conditions affecting concrete*[3][1].

[1] At present at the draft stage.

[2] As amended in Annex A.

[3] Reference applies to the draft proposal ISO/DP 9690:1987 and shall be rediscussed during the lifetime of ENV 206.

2.3 Optional references

ISO 4109:1980, *Fresh concrete — Determination of the consistency — Slump test.*

ISO 4110:1979, *Fresh concrete — Determination of the consistency — Vebe test.*

ISO 4111:1979, *Fresh concrete — Determination of the consistency — Degree of compactibility (Compaction index).*

ISO 6275:1982, *Concrete, hardened — Determination of density.*

ISO 6276:1982, *Concrete, compacted fresh — Determination of density.*

ISO 6782:1982, *Aggregates for concrete — Determination of bulk density.*

ISO 6783:1982, *Coarse aggregates for concrete — Determination of particle density and water absorption — Hydrostatic balance method.*

ISO 7033:1987, *Particle density and water absorption of fine and coarse aggregates for concrete (Pycnometer method).*

ISO 7034, *Cores of hardened concrete — Taking, examination and testing in compression*[4].

ISO 8045, *Concrete, hardened — Determination of rebound number using the rebound hammer*[4].

ISO 8046, *Concrete, hardened — Determination of pull-out strength*[4].

ISO 8047, *Concrete, hardened — Determination of ultrasonic pulse velocity*[4].

ISO 9812, *Fresh concrete — Determination of consistency — Flow test*[4].

RILEM CPC7, *Direct tension (Final recommendation, 1975).*

EN 45011, *General criteria for certification bodies operating product certification.*

EN 45014, *General criteria for declaration of conformity.*

2.4 Other references

Eurocode 2, *Common unified rules for concrete structures*[4];

Eurocode 4, *Common unified rules for composite steel and concrete structures*[4];

3 Definitions

3.1
concrete

material formed by mixing cement, coarse and fine aggregate and water and produced by the hardening of the cement paste (cement and water); besides these basic components, it may also contain admixtures and/or additions

NOTE If the maximum particle size of the aggregate is 4 mm or less, the resulting material is termed mortar, not concrete.

3.2
fresh concrete

concrete still in the plastic state and capable of being compacted by normal methods

3.3
hardened concrete

concrete which has hardened and developed a certain strength

3.4
site mixed concrete

concrete batched and mixed on or near the construction site by the user

3.5
ready mixed concrete

concrete batched in a plant outside the construction site or on the construction site, mixed in a stationary mixer or a truck mixer and delivered by the producer to the user in the fresh condition ready for use either on the construction site or into a vehicle of the user

3.6
normal-weight concrete

concrete having an oven-dry (105 °C) density greater than 2 000 kg/m^3 but not exceeding 2 800 kg/m^3

3.7
light-weight concrete

concrete having an oven-dry density of not more than 2 000 kg/m^3. It is entirely or partly produced by the use of aggregate that has a porous structure (light-weight aggregate; see definition 3.18)

3.8
heavy-weight concrete

concrete having an oven-dry density greater than 2 800 kg/m^3

3.9
truck mixer

concrete mixing unit generally mounted on a self-propelled chassis capable of producing and delivering a homogeneously mixed concrete. A truck mixer may be used as a truck agitator

3.10
truck agitator

equipment mounted on a self-propelled chassis and capable of maintaining mixed concrete in a thoroughly mixed and homogeneous mass during transit

[4] At present at the draft stage.

3.11
non-agitating equipment

dump truck, transport hoppers or other equipment used for transporting concrete without agitating

3.12
batch

quantity of concrete mixed in one cycle of operations of a batch mixer, or the quantity of concrete conveyed ready-mixed in a vehicle, or the quantity discharged during 1 min from a continuous mixer

3.13
delivery

the process of handing over the concrete to the user normally by discharging from the ready mixed concrete truck

3.14
admixture

product which is added in small quantities by mass of the cement before or during mixing or during an additional mixing operation, causing the required modifications to the normal properties

3.15
addition

finely divided inorganic material that may be added to concrete in order to improve certain properties or to achieve special properties. There are two types of additions

— nearly inert additions (type I); and

— pozzolanic or latent hydraulic additions (type II).

3.16
aggregate

material consisting of uncrushed and/or crushed natural and/or artificial mineral substances with particle sizes and shapes suitable for the production of concrete

3.17
normal-weight aggregate

aggregate with a particle density between 2 000 kg/m^3 and 3 000 kg/m^3, when determined according to ISO 6783 or ISO 7033

3.18
light-weight aggregate

aggregate consisting of grains with a porous structure and with a particle density of less than 2 000 kg/m^3, when determined according to ISO 6783 or ISO 7033

3.19
heavy-weight aggregate

aggregate having a particle density appreciably greater than 3 000 kg/m^3, when determined according to ISO 6783 or ISO 7033

3.20
cement (hydraulic binder)

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

3.21
effective water content

mixing water plus water already present on the surface of the aggregates and in the admixtures and additions (and possibly water from added ice or steam heating)

3.22
water/cement ratio

ratio of effective water content to cement content in the concrete

3.23
designed mix

mix for which the user is responsible for specifying the required performance and additional characteristics and the producer is responsible for providing a mix which complies with the required performance and additional characterisitics

3.24
prescribed mix

mix for which the user specifies the composition of the mix and materials to be used. The producer is responsible for providing the specified mix but is not responsible for the performance of the concrete

3.25
initial test

test or tests to check, before the concrete is used, how it shall be composed in order to meet all the performance requirements in the fresh and hardened stage, account being taken of the constituent materials to be used and the particular conditions on site

3.26
entrained air

microscopic air bubbles intentionally incorporated in concrete during mixing, usually by use of a surface active agent; typically between 10 µm and 100 µm diameter and spherical or nearly so

3.27
entrapped air

air voids in concrete which are not purposely entrained and which are significantly larger and less useful than those of entrained air, 1 mm or larger in size

4 Constituent materials

4.1 Cements

Portland cement (CEI)[5], Portland composite cement (CEII)[5], blastfurnace cement (CEIII)[5] and pozzolanic cement (CEIV)[5] shall comply with EN 197-1 to EN 197-3[6] [7]. Other cements shall comply with the national standards or regulations valid in the place of use of the concrete.

4.2 Aggregates

Aggregates shall comply with the requirements of the national standards or regulations valid in the place of use of the concrete. Aggregates shall not contain harmful constituents in such quantities as may be detrimental to the durability of the concrete or cause corrosion of the reinforcement.

4.3 Mixing water

The mixing water shall comply with the requirements of national standards or regulations valid in the place of use of the concrete. Water shall not contain harmful constituents in such quantities as may be detrimental to the setting, hardening and durability of the concrete or cause corrosion of the reinforcement. In general in Europe, drinking water from public supply is suitable for making concrete.

4.4 Admixtures

Admixtures shall comply with the requirements of the national standards or regulations valid in the place of use of the concrete. Admixtures shall not contain harmful constituents in such quantities as may be detrimental to the durability of the concrete or cause corrosion of the reinforcement.

4.5 Additions

Additions shall comply with the requirements of the national standards or regulations valid in the place of use of the concrete. Additions shall not contain harmful constituents in such quantities as may be detrimental to the durability of the concrete or cause corrosion of the reinforcement.

5 Basic requirements for concrete composition

5.1 General

The concrete mix proportions including cement, aggregates and water (and additions and admixtures where used) shall be selected to satisfy all the performance criteria for fresh and hardened concrete including consistency, density, strength, durability, protection of embedded steel against corrosion. The composition of the concrete shall give a workability compatible with the method of construction to be used.

The mix shall be designed so as to minimize possible segregation and bleeding of the fresh concrete.

In all cases concrete shall fulfil the basic requirements according to 5.2 to 5.10 and clause 6. For additional requirements with respect to the performance of concrete see clause 7.

5.2 Structure of concrete

Concrete shall have a composition such that after compaction it has a closed structure, i.e. when compacted in a standard manner[8], the air content by volume shall not be more than 3 % for nominal aggregate size ≥ 16 mm and 4 % for nominal aggregate size < 16 mm, entrained air and aggregate pores excepted.

5.3 Types of cement, cement content and water/cement ratio

The type of cement shall be chosen taking into account the application of the concrete (plain, reinforced or prestressed), the heat development of the concrete in the structure, the dimensions of the structure and the environmental conditions to which the structure is exposed.

For concrete made with aggregates of nominal maximum size ≤ 32 mm the minimum cement content and the maximum water/cement ratio depend on the environmental conditions and on the required properties of the concrete cover to the reinforcement[9]. They shall be chosen from Table 3.

Any special requirements for concrete properties, e.g. water impermeability, shall also be considered in choosing the cement content.

[5] Cement types and classes are defined in EN 197-1 and EN 197-2 (June 1988 draft).

[6] Until EN 197 is available comparable cements may be used that comply with the national standards or regulations valid in the place of use of the concrete.

[7] Where in ENV 206 reference is made to certain types or classes of cement these are based on the definitions of prEN 197-1 and prEN 197-2

[8] i.e., in accordance with the principles laid down in ISO 2736-2 for compaction of test specimens.

[9] For the thickness of the concrete cover to reinforcement see the provisions of Eurocode 2.

For concrete with aggregate sizes substantially exceeding 32 mm, e.g. mass concrete, lower values of the cement content than those given in Table 3 may be acceptable.

For minimum cement contents and maximum water/cement ratio laid down in this prestandard only those cements listed in 4.1 shall be taken into account. In special cases when pozzolanic or latent hydraulic additions are added to the mix, national standards or regulations, valid in the place of use of the concrete, may state if and how the minimum or maximum values are allowed to be modified.

5.4 Particle size of aggregates

The maximum aggregate size has to be chosen so that the concrete can be placed and compacted around the reinforcement in a satisfactory way without becoming segregated.

The positioning of the reinforcing bars shall be chosen in such a way that the concrete can be placed and compacted in a satisfactory way without becoming segregated.

The nominal maximum size of the aggregate shall not exceed

— one quarter of the smallest dimension of the structural member;

— the distances between the reinforcing bars less 5 mm, unless special provisions are taken, e.g. grouping the reinforcing bars;

— 1,3 times the thickness of the concrete cover (this restriction is not necessary for exposure class 1 in Table 2).

NOTE The maximum nominal size of the aggregates may be required to be related to the nominal minimum cover (see, e.g. Eurocode 2), to achieve a good bond.

5.5 Chloride content of concrete

The chloride ion content of a concrete shall not exceed the values laid down in the national standards or regulations valid in the place of use of the concrete. In the absence of such values those given in Table 1 shall be adopted.

Table 1 — Maximum chloride content of concrete

Concrete	Cl^- by mass of cement
Plain concrete	1 %
Reinforced concrete	0,4 %
Prestressed concrete	0,2 %

Calcium chloride and chloride based admixtures shall not be added to reinforced concrete, prestressed concrete and concrete containing embedded metal, unless their use is permitted by the national standards or regulations valid in the place of use of the concrete.

5.6 Consistence during casting

The consistence shall be such that the fresh concrete is workable without becoming segregated and such that it can be fully compacted under the given site conditions.

To ensure proper compaction of concrete cast in situ it is recommended that the consistence of the concrete at the time of placing should be equal to slump class S3[10)] or have a flow class F3[10)] unless other measures are taken.

5.7 Resistance to alkali-silica reaction

Some aggregates may contain particular varieties of silica susceptible to attack by alkalis (Na_2O and K_2O) originating from the cement or other sources. In the presence of moisture an expansive reaction can occur which may result in cracking or disruption of the concrete. Under such conditions one or more of the following precautions should be taken

— limit the total alkali content of the concrete mix;

— use a cement with a low effective alkali content;

— change the aggregates;

— limit the degree of saturation of the concrete, e.g. by impermeable membranes.

For further details the requirements of the national standards or regulations valid in the place of use of the concrete shall be followed taking account of previous long term experience with the particular combination of cement and aggregate.

5.8 Admixtures

The total amount of admixtures, if any, shall not exceed 50 g/kg cement and should not be less than 2 g/kg cement in the mix.

Smaller quantities of admixtures are only allowed if they are dispersed in part of the mixing water.

Liquid admixtures in quantities exceeding 3 l/m^3 of concrete shall be taken into account when calculating the water/cement ratio.

5.9 Additions

Additions may only be added to the mix in such quantities that they do not impair the durability of the concrete and do not cause corrosion of the reinforcement.

[10)] Consistence classes are defined in ISO 4103 (see also 7.2.1)

The national standards or regulations valid in the place of use of the concrete shall be followed.

5.10 Concrete temperature

Unless special provisions are made the temperature of fresh concrete should not exceed 30 °C and should not be less than 5 °C in the time between mixing and placing (for heat curing see 10.7).

6 Requirements for durability

6.1 General

To produce a durable concrete, which protects the reinforcing steel against corrosion and withstands satisfactorily the environmental and working conditions to which it is exposed during the intended lifetime, the following factors have to be taken in consideration:

a) choice of suitable constituents, containing no harmful components which may be detrimental to the durability of the concrete and cause corrosion of the reinforcement (see, e.g. clause 4, 5.5);

b) choice of a concrete composition such that the concrete:

— satisfies all specified performance criteria for fresh and hardened concrete (see, e.g. clause 7);

— can be placed and compacted to form a dense cover to the reinforcement (see, e.g. clause 5);

— withstands internal actions (see, e.g. 5.7);

— withstands external actions, e.g. environmental influences, e.g. weather, gases, liquids and soil (see 6.2);

c) mechanical attacks, e.g. abrasion (see 7.3.1.4);

d) mixing, placing and compacting of the fresh concrete such that the concrete constituents are distributed uniformly in the mix, are not segregated and that the concrete achieves a closed structure (see, e.g. clause 9 and clause 10);

e) curing of the concrete such that particularly the surface zone (cover to the reinforcement) achieves the potential properties to be expected from the mix (see 10.6).

All these factors shall be controlled and verified by production control by the contractor, subcontractor or supplier, each within his specific task (see 11.2).

6.2 Resistance to environmental actions

6.2.1 *Classes of exposure related to environmental conditions*

Environment in this context means those chemical and physical actions to which the concrete is exposed and which result in effects that are not considered as loads in structural design.

These environmental conditions are classified in Table 2.

6.2.2 *Durability requirements related to environmental conditions*

The limiting values for composition and properties of plain, reinforced and prestressed concrete are given in Table 3.

The minimum requirements for plain concrete are only applicable if the concrete does not contain embedded steel (reinforced and permanent inserts) which has to be protected against corrosion.

Additionally when required by national standards or regulations valid in the place of use of the concrete minimum strength grades may be specified.

If the requirements for water/cement ratio and minimum cement content given in Table 3 are satisfied the strength classes given in Table 20 will normally be achieved.

7 Concrete properties and methods of verification

7.1 General

The properties of fresh and hardened concrete which may be specified and the corresponding methods of verification which shall be used when required are detailed in 7.2 and 7.3.

7.2 Fresh concrete

7.2.1 *Consistence*

The consistence of concrete shall be determined either by means of the slump test in accordance with ISO 4109 or of the Vebe test in accordance with ISO 4110 or of the compaction test in accordance with ISO 4111 or of the flow table test in accordance with ISO 9812 or of an alternative test method to be agreed upon.

NOTE The different classes of consistence in Table 4 to Table 7 are not directly related.

The consistence of concrete is classified according to ISO 4103 as shown in Table 4, Table 5, Table 6 and Table 7.

Table 2 — Exposure classes related to environmental conditions

Exposure class		Examples of environmental conditions
1 Dry environment		interior of dwellings or offices[a]
2 Humid environment	a Without frost	— interior of buildings where humidity is high (e.g. laundries) — exterior components — components in non-aggressive soil and/or water
	b With frost	— exterior components exposed to frost — components in non-aggressive soil and/or water and exposed to frost — interior components where the humidity is high and exposed to frost
3 Humid environment with frost and de-icing agents		— interior and exterior components exposed to frost and de-icing agents
4 Seawater environment	a Without frost	— components completely or partially submerged in seawater, or in the splash zone — components in saturated salt air (coastal area)
	b With frost	— components partially submerged in seawater or in the splash zone and exposed to frost — components in saturated salt air and exposed to frost
The following classes may occur alone or in combination with the above classes:		
5 Aggressive chemical environment[b]	a	— slightly aggressive chemical environment (gas, liquid or solid) — aggressive industrial atmosphere
	b	moderately aggressive chemical environment (gas, liquid or solid)
	c	highly aggressive chemical environment (gas, liquid or solid)

[a] This exposure class is valid as long as during construction the structure or some of its components is not exposed to more severe conditions over a prolonged period of time.

[b] Chemically aggressive environments are classified in ISO 9690. The following equivalent exposure conditions may be used:
Exposure class 5a: ISO classification A1G, A1L, A1S
Exposure class 5b: ISO classification A2G, A2L, A2S
Exposure class 5c: ISO classification A3G, A3L, A3S

Table 3 — Durability requirements related to environmental exposure

	Exposure class according to Table 2								
	1	2a	2b	3	4a	4b	5a	5b	5c[a]
Max. w/c ratio for[b]									
— plain concrete	—	0,70							
— reinforced concrete	0,65	0,60	0,55	0,50	0,55	0,50	0,55	0,50	0,45
— prestressed concrete	0,60	0,60							
Min. cement content[b] in kg/m^3 for									
— plain concrete	150	200	300				200		
— reinforced concrete	260	280	280	300	300	300	280	300	300
— prestressed concrete	300	300	300				300		
Min. air content of fresh concrete in % for nominal max. aggregate size of[c]			[d]	[d]		[d]			
— 32 mm	—	—	4	4	—	4	—	—	—
— 16 mm	—	—	5	5	—	5	—	—	—
— 8 mm	—	—	6	6	—	6	—	—	—
Frost resistant aggregates[f]	—	—	Yes	Yes	—	Yes	—	—	—
Impermeable concrete according to clause 7.3.1.5	—	—	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Types of cement for plain and reinforced concrete according to EN 197							Sulphate resisting cement[e] for sulphate contents > 500 mg/kg in water > 3 000 mg/kg in soil		
	These values of w/c ratio and cement content are based on cement where there is long experience in many countries. However at the time of drafting this prestandard experience with some of the cements standardized in EN 197 is limited to local climatic conditions in some countries. Therefore during the life of this prestandard, particularly for exposure classes 2b, 3, 4b the choice of the type of cement and its composition should follow the national standards or regulations valid in the place of use of the concrete. Alternatively the suitability for use of the cements may be proved by testing the concrete under the intended conditions of use. Additionally cement CEI may be used generally for prestressed concrete. Other types of cement may be used if experience with these types is available and the application is allowed by the national standards or regulations valid in the place of use of the concrete.								

[a] In addition, the concrete shall be protected against direct contact with the aggressive media by coatings unless for particular cases such protection is considered unnecessary.

[b] For minimum cement content and maximum water/content ratio laid down in this prestandard only cement listed in 4.1 shall be taken into account. When pozzolanic or latent hydraulic additions are added to the mix, national standards or regulations, valid in the place of use of the concrete, may state if and how the minimum or maximum values respectively are allowed to be modified.

[c] With a spacing factor of the entrained air void system < 0,20 mm measured on the hardened concrete.

[d] In cases where the degree of saturation is high for prolonged periods of time. Other values or measures may apply if the concrete is tested and documented to have adequate frost resistance according to the national standards or regulations valid in the place of use of the concrete.

[e] The sulphate resistance of the cement shall be judged on the basis of national standards or regulations valid in the place of use of the concrete.

[f] Assessed against the national standards or regulations valid in the place of use of the concrete.

Table 4 — Slump classes

Class	Slump in mm
S1	10 to 40
S2	50 to 90
S3	100 to 150
S4	≥ 160
The measured slump is to be rounded off to the nearest 10 mm.	

Table 5 — Vebe classes

Class	Vebe in seconds
V0	≥ 31
V1	30 to 21
V2	20 to 11
V3	10 to 5
V4	≤ 4

Table 6 — Compaction classes

Class	Degrees of compactibility
C0	≥ 1,46
C1	1,45 to 1,26
C2	1,25 to 1,11
C3	1,10 to 1,04

Table 7 — Flow classes

Class	Flow diameter in mm
F_1	≤ 340
F_2	350 to 410
F_3	420 to 480
F_4	490 to 600

For concrete of high workability, e.g. when high water reducing admixtures are used, the flow table test should be used.

7.2.2 *Air content*

The air content of freshly mixed concrete shall be determined in accordance with ISO 4848.

7.2.3 *Density of compacted fresh concrete*

The density of compacted fresh concrete shall be determined according to ISO 6276 or an alternative method to be agreed upon.

7.2.4 *Water/cement ratio and cement content*

The water/cement ratio of concrete shall be calculated and checked on the basis of results from measurement of the weight of added cement, water and aggregates together with the effective water content of the aggregates (for liquid admixtures see **5.8**).

Where determination of the water/cement ratio of the fresh concrete by analysis is required the test method shall be agreed upon[11].

7.3 Hardened concrete

7.3.1 *Resistance to mechanical effects*

7.3.1.1 *Compressive strength*

The compressive strength of concrete is expressed in terms of the characteristic strength defined as that value of strength below which 5 % of the population of all possible strength measurements of the specified concrete are expected to fall. The strength shall be determined in accordance with ISO 4012 on moulded specimens — either 150 mm cubes as $f_{ck_{cube}}$ or 150/300 mm cylinders as $f_{ck_{cyl}}$ — aged 28 days, complying with ISO 1920 and made and cured according to ISO 2736.

Whether the compressive strength will be assessed on the basis of cube or cylinder tests shall be specified or agreed upon before the start of construction work.

Concrete is classified according to its compressive strength as given in Table 8 which is based on the classification by cylinder strength in Eurocode 2 for design.

For production and quality control reasons, the values underlined in Table 8 are recommended for specifying concrete.

For light-weight concrete the same strength classes apply preceded by the symbol LC.

For particular uses it may be necessary to define a minimum compressive strength of the moulded specimens at an earlier age or at a later age or after storage under special conditions (e.g. heat treatment according to **10.7**).

7.3.1.2 *Tensile strength*

The tensile strength of concrete shall be specified and determined by means either of the splitting tensile strength according to ISO 4108 or of the flexural tensile strength according to ISO 4013.

[11] In cases where the ratio of mass of aggregates to cement is known, the water/cement ratio may be determined by the Thaulow method (S. Thaulow *Field testing of Concrete, New and Simplified Methods for Testing Concrete and its Aggregates* Norsk Cementforening, Oslo, Norway 1952).

Table 8 — Strength classes of concrete

Strength class	C12/15	C16/20	C20/25	C25/30	C30/37	C35/45	C40/50	C45/55	C50/60
$f_{ck_{cyl}}$ [a] N/mm^2	12	16	20	25	30	35	40	45	50
$f_{ck_{cube}}$ N/mm^2	15	20	25	30	37	45	50	55	60
[a] $f_{ck_{cyl}}$ is identical with $f_{ck_{ck}}$ used in the Eurocodes.									

The tensile strength of concrete may also be expressed by means of the axial tensile strength which can be measured according to RILEM CPC7.

NOTE The results obtained by these different test methods are not interchangeable, but relationships for design purpose may be established (see, e.g. the relevant clauses for tensile strength in Eurocode 2).

7.3.1.3 *Strength development*

The strength development shall be specified by compressive strength tests at concrete ages to be agreed upon. If the influence of the site conditions on the strength development has to be taken into account, the special curing conditions for the specimens shall be agreed upon.

7.3.1.4 *Resistance to abrasion*

The resistance to abrasion shall be determined according to the national standards or regulations valid in the place of use of the concrete.

To produce a concrete with a high resistance to abrasion the following provisions are recommended:

— concrete strength class not less than C30/37;

— well graded and hard aggregates with a rough surface texture and a high proportion of coarse particles;

— double the duration of curing as given in 10.6.3;

— in the case of particularly severe abrasion provision of a special wearing surface.

7.3.1.5 *Resistance to water penetration*

The mix shall be considered suitable for water impermeable concrete if the resistance to water penetration when tested according to ISO 7031 results in maximum values of penetration less than 50 mm and mean average values of penetration less than 20 mm. The water/cement ratio shall not exceed 0,55.

7.3.2 *Density*

Concrete is classified as normal-weight concrete (symbol C), light-weight concrete (symbol LC) and heavy-weight concrete (symbol HC) on the basis of its oven-dry density. See definitions 3.6, 3.7 and 3.8.

The classification of light-weight concrete by density is given in Table 9.

The density shall be determined in accordance with ISO 6275. In cases where the ratio of oven-dry density to apparent density of the hardened concrete is known the apparent density may be determined in accordance with ISO 4012.

8 Specification of concrete

8.1 General

Concrete may be specified as a designed mix (see definition 3.23) referring to concrete properties given in clause 7 or as a prescribed mix (see definition 3.24) by prescribing the composition on the basis of results of initial tests (see definition 3.25) or information obtained from long-term experience with comparable concrete.

The information to be provided by the specifier or the contractor, as appropriate:

— in the case of designed mixes is indicated in 8.2;

— in the case of prescribed mixes is indicated in 8.3.

8.2 Data for specifying designed mixes

8.2.1 *General*

Designed mixes are to be specified by means of basic data from 8.2.2, to be indicated in all cases, and additional data from 8.2.3, to be indicated if required for special conditions.

8.2.2 *Basic data*

a) strength class;

b) nominal maximum size of aggregate;

c) basic limitations on composition according to the use of the concrete (e.g. exposure classes; plain, reinforced or prestressed concrete). See clauses 5 and 6;

In the case of ready mixed concrete (provided by the contractor)

d) consistence class.

Table 9 — Classification of light-weight concrete

Density class	1,0	1,2	1,4	1,6	1,8	2,0
kg/m^3	901 to 1 000	1 001 to 1 200	1 201 to 1 400	1 401 to 1 600	1 601 to 1 800	180 to 2 000

8.2.3 *Additional data if required for special conditions*

To be given for a) and b) as performance requirements and test methods, if possible.

a) Characteristics of the hardened concrete, e.g.

— density, e.g. for light-weight concrete or heavy-weight concrete;

— resistance to water penetration;

— resistance to alternating freezing and thawing;

— resistance to combined action of frost and de-icing agents;

— resistance to chemical attack;

— resistance to abrasion;

— resistance to high temperatures;

— other additional technical requirements.

b) Characteristics of the mix, e.g.

— type of cement;

— consistence class;

— air content;

— accelerated strength development;

— heat development during hydration;

— retarded hydration;

— special requirements for aggregates;

— special requirements concerning resistance to alkali-silica reaction;

— special requirements for the temperature of the fresh concrete;

— other additional technical requirements.

c) In the case of ready mixed concrete additional conditions relevant to transport and procedures on site (provided by the contractor), e.g.

— delivery time and rate;

— special transport on site

— pumping

— belt conveyor;

— limitation of type (agitating/non-agitating equipment), size, height or weight of transport vehicle.

8.3 Data for specifying prescribed mixes

8.3.1 *General*

Prescribed mixes are to be specified by basic data from 8.3.2 to be indicated in all cases and additional data from 8.3.3 to be indicated if required for special conditions.

8.3.2 *Basic data*

a) cement content per cubic metre of compacted concrete;

b) cement types and strength class;

c) consistence class of the fresh concrete or the w/c ratio;

d) types of aggregate;

e) nominal maximum size and grading of aggregate;

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

g) if admixtures or additions are used, sources of the concrete constituents.

8.3.3 *Additional data*

a) For the mix, e.g.

— sources of concrete constituents;

— additional requirements for aggregates including any special gradings;

— special requirements regarding the temperature of the fresh concrete on delivery;

— other additional technical requirements.

b) In the case of ready mixed concrete additional conditions relevant to transport and procedures on site, e.g.

— delivery time and rate;

— limitation of type (agitating/non-agitating equipment), size, height or weight of transport vehicle.

9 Production of concrete

9.1 Personnel, equipment and installations

9.1.1 *Personnel*

The personnel involved in the production and the control of concrete shall have appropriate knowledge, training and experience for its specific task.

At the production place there shall be a person with appropriate knowledge and experience who shall be responsible for the production and, in the case of ready mixed concrete, also for the delivery. He or his appropriately trained representative shall be present while the production is running.

There shall be a person in charge of the production control who shall have appropriate knowledge and experience of concrete technology, production, testing and control systems.

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

9.1.2 *Equipment and installations*

9.1.2.1 *Storage of materials*

Adequate supplies of materials — cements, aggregates, additions and/or admixtures — shall be available to ensure that a planned rate of production and delivery can be maintained.

Different types of materials shall be transported and stored so as to avoid intermingling, contamination or deterioration. In particular

— Cement and additions shall be protected from moisture and impurities during transportation and storage. The various types of cement and additions shall be clearly marked and so stored that error is excluded. Cement in bags should be stored so that it may be used in the order of delivery.

— If aggregates of different gradings or of different types are separately delivered, they shall not be inadvertently mixed. Segregation of the different fractions shall be prevented.

— Admixtures shall be transported and stored so that their quality is not affected by physical and chemical influences (frost, high temperatures, etc). They shall be clearly marked and stored so that error is excluded.

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

9.1.2.2 *Batching equipment*

The performance of the batching equipment shall be such that under practical conditions of operation the accuracies stated in 9.2 can be obtained.

The accuracy of the measuring equipment shall comply with the relevant national requirements or regulations valid in the place of production of the concrete. In the absence of such requirements, the minimum values in Table 10 apply.

Table 10 — Accuracy of measuring equipment

Position on the scale or range of a digital indicator	Accuracy	
	On installation	During operation
0 to 1/4 full scale or range	0,5 % of 1/4 scale or 1/4 range value	1,0 %
1/4 to full scale or range	0,5 % of the actual reading	1,0 %

Each division of the scale or digital indicator should represent a mass not greater than 1/500 of the capacity of the scale or range of digital equipment.

9.1.2.3 *Mixers*

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

Truck mixers shall be so equipped as to enable the concrete to be delivered in a homogeneously mixed state. In addition, they shall be provided with suitable measuring and dispensing equipment, if mixing water or admixtures are to be added on the site.

9.2 Batching of constituent materials

For the concrete mix(es) to be produced, a recorded mixing instruction shall be available giving details of the type and quantity of the constituent materials.

For the batching of the constituent materials, the accuracies (of equipment and its operation) shall be as given in Table 11.

Table 11 — Accuracies for batching of constituent materials

Constituent material	Accuracy
Cement	± 3 % of required quantity
Water	
Total aggregates	
Additions	
Admixtures	± 5 % of required quantity

Cement, aggregates and additions in the form of powders should be batched by weight; other methods are permissible if the required batching accuracies can be achieved.

The water may be batched by weight or by volume.

Admixtures and liquid additions may be measured by weight or by volume.

9.3 Mixing of concrete

Mixing of the constituent materials shall be carried out in a mechanical mixer and be continued until a uniform mixture is obtained. Mixing shall be considered to commence from the moment when all the materials required for the batch are in the mixer.

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

When admixtures are added in small quantities (see 5.8), the admixtures shall be dispersed in a part of the mixing water.

When high water reducing admixtures have to be added at the site on account of the short duration of their effects, the concrete should be uniformly mixed before the admixture in question is added. After making the addition the concrete shall be remixed until the admixture has been completely dispersed throughout the batch and has become fully effective.

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

10 Transport, placing and curing of fresh concrete

10.1 Personnel

The personnel involved in transport, placing and curing of concrete shall have appropriate knowledge, training and experience in its specific task.

At the building site there shall be a person with appropriate knowledge and experience who is in charge of the reception of the concrete and is responsible for the transport on site, placing and curing operations. He or his appropriately trained representative shall be present while the concrete is placed.

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

10.2 Transport

Appropriate measures shall be taken to prevent segregation, loss of constituents or contamination during transport and discharge.

The maximum permissible transport duration depends essentially on the composition of the concrete and the atmospheric conditions.

10.3 Delivery

10.3.1 *Information from the producer in the case of ready mixed concrete*

The user may require information on the mix composition to permit proper placing and curing of the fresh concrete as well as the assessment of the strength development in the structure. Such information shall be given by the producer on request before or during the delivery as appropriate. The following information shall be provided 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 mix, e.g. from production control or from initial tests.

This information may also be provided by reference to the producer's catalogue of concrete mixes in which details of strength class, consistence classes, batch weights and other relevant details are given.

10.3.2 *Delivery ticket in the case of ready mixed concrete*

Before discharging the concrete, 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;

— name of user;

— name and location of the site;

— specification, details or references to specifications, e.g. code number, order number;

— amount of concrete in cubic metres[12];

— name or mark of the certification body where appropriate.

In addition the delivery ticket shall give details of the following.

For a designed mix:

— strength class;

— exposure class or corresponding limitation on mix composition;

— consistence class;

— type of cement and strength class;

— type of admixture and addition, if any;

— special properties;

For a prescribed mix:

— details of the composition, e.g. cement content, type of admixture, if any;

— consistence class.

10.3.3 *Delivery in the case of concrete, site mixed by the contractor*

The requirements of 10.3.2 for a ticket may be also relevant for site mixing by the contractor, when the site is large or several types of concrete are involved (see also 11.2.1).

[12] 1 cubic metre of ready mixed concrete is the quantity of fresh concrete which, when compacted in accordance with the procedures given in ISO 2736 for the compaction of test specimens, occupies a volume of one cubic metre.

10.4 Consistence at delivery

If at delivery, the consistence of the concrete is not as specified, the concrete shall be rejected. However, if the consistence is less than specified and the concrete is still in a truck mixer, the consistence may be brought up to the required value by adding water and/or admixtures (high water reducing admixtures), provided this is permitted by the specification and any specified maximum permissible water/cement ratio is not exceeded[13]).

10.5 Placing and compacting

Concrete shall be placed as soon as possible after mixing to minimize any loss of workability.

While placing, provisions shall be taken to prevent segregation when concrete is allowed to fall freely.

Concrete shall be thoroughly compacted during placing, and worked around the reinforcement, tendons or duct formers, embedded fixtures and into corners of the formwork to form a solid void-free mass particularly in the cover zone.

Special requirements for surface finish shall be specified additionally.

While placing and compacting, care shall be taken to avoid displacing and damage of reinforcement, tendons, ducts, anchorages and formwork.

When vibrators are used, vibration should be applied continuously during the placing of each batch of concrete until the expulsion of air practically ceases and in a manner which does not promote segregation.

10.6 Curing and protection

10.6.1 *General*

In order to obtain the potential properties to be expected from the concrete especially in the surface zone, thorough curing and protection for an adequate period is necessary.

Curing and protection should start as soon as possible after the compaction of the concrete.

Curing is prevention against:

— premature drying, particularly by solar radiation and wind.

Protection is prevention against:

— leaching by rain and flowing water;

— rapid cooling during the first few days after placing;

— high internal temperature differences;

— low temperature or frost;

— vibration and impact which may disrupt the concrete and interfere with its bond to the reinforcement.

10.6.2 *Methods of curing*

The curing method shall be defined before the commencement of work on site.

The principal methods for curing concrete are

— keeping the formwork in place;

— covering with plastic films;

— placing of wet coverings;

— sprinkling with water;

— application of curing compounds which form protective membranes.

The methods can be used separately or in combination.

10.6.3 *Curing time*

The required curing time depends on the rate at which a certain impermeability (resistance to penetration of gases or liquids) of the surface zone (cover to the reinforcement) of the concrete is reached. Therefore, curing times shall be determined by one of the following:

— from the maturity based on degree of hydration of the concrete mix and ambient conditions;

— in accordance with local requirements;

— in accordance with the minimum periods given in Table 12.

In cases where the concrete is exposed to severe abrasion (see 7.3.1.4) or to severe environmental conditions (exposure classes 3, 4, 5b and 5c according to Table 2) the curing times given in Table 12 should be substantially increased.

Depending on the type and use of the structural element (e.g. the intended finish) the minimum curing time given in Table 12 should also be used for exposure class 1.

The strength development of concrete may be estimated using the information given in Table 13.

[13]) If in a truck mixer at site more water is added than is required for the specified consistence or maximum water/cement ratio the party which decided to add such water is responsible for the modification of the specification and the technical consequences.

Table 12 — Minimum curing times in days for exposure classes 2 and 5a

Strength development of concrete	Rapid			Medium			Slow		
Temperature of concrete during curing above ° C	5	10	15	5	10	15	5	10	15
Ambient conditions during curing									
I									
No direct sunshine, relative humidity of surrounding air not lower than 80 %	2	2	1	3	3	2	3	3	2
II									
Exposed to medium sunshine or medium wind velocity or relative humidity not lower than 50 %	4	3	2	6	4	3	8	5	4
III									
Exposed to strong sunshine or high wind velocity or relative humidity below 50 %	4	3	2	8	6	5	10	8	5

Table 13 — Strength development of concrete

Rate of strength development	W/C	Cement strength classes
Rapid	< 0,5	42,5 R
Medium	0,5 to 0,6	42,5 R
	< 0,5	32,5 R and 42,5
Slow	All other cases	

For cement types CEII, CEIII and CEIV longer curing times may be appropriate.

10.6.4 *Protection against thermal cracking of the surface*

The hardening concrete shall be protected against damaging effects due to internal or external restraint caused by heat generated in the concrete.

Where no cracking is permitted, adequate measures shall be taken to ensure than the tensile stresses caused by temperature differences are less than the instantaneous tensile strength.

To avoid surface cracking caused by heat generated in the concrete under normal conditions the temperature difference between the centre and the surface shall be less than 20 °C.

10.6.5 *Protection against freezing*

The period of protection against freezing may be calculated from the maturity of the concrete. Alternatively protection is no longer needed if a compressive strength of 5 N/mm^2 is obtained.

10.7 Heat treatment

For curing of concrete members which are to be subject during their use to exposure classes 2 to 5 (Table 2) limitations with regard to heat treatment (steam curing) shall be observed as follows:

— concrete temperature during the first 3 h after mixing shall not exceed 30 °C and shall not be higher than 40 °C during the first 4 h;

— the rate of temperature increase shall not exceed 20 K/h;

— the average maximum temperature of the concrete shall not exceed 60 °C (individual values < 65 °C);

— the concrete shall be cooled at a rate not exceeding 10 K/h;

— throughout the curing procedure and while cooling, the concrete shall be protected against moisture loss.

These requirements do not apply when the special technology of direct steam injection into the mixer is adopted or when there is sufficiently documented positive experience with other conditions of heat treatment for well defined constituent materials, especially cement.

10.8 Removal of formwork

The formwork may be struck when an adequate strength of concrete has been reached with respect to the load carrying capacity and the deflections of the structure and when the formwork is no longer required for curing.

11 Quality control procedures

11.1 General

Concrete production, placing and curing shall be subject to quality control procedures as given in 11.2 and 11.3.

Quality control is defined as a combination of actions and decisions taken in compliance with specifications and checks to ensure that the specified requirements are satisfied.

Quality control consists of two distinct, but interconnected parts, namely production control according to 11.2 and conformity control according to 11.3.

11.2 Production control

11.2.1 *General*

Production control comprises all measures necessary to maintain and regulate the quality of the concrete in conformity with specified requirements. It includes inspections and tests and involves the use of test results with regard to equipment, basic materials, fresh concrete and hardened concrete. It also comprises inspection prior to concreting and inspection concerning transport, placing, compacting and curing of fresh concrete.

Production control shall be carried out by the contractor, subcontractors and suppliers each within the scope of their specific task in the process of producing, placing and curing the concrete.

All necessary facilities and equipment shall be available to carry out the necessary inspections and tests on equipment, materials and concrete.

All relevant data from the production control — on site, in the ready mixed concrete plant or in the precast concrete factory — shall be recorded in a log book or other document, e.g.:

— names of the suppliers of cement, aggregates, admixtures and additions;

— numbers of the delivery tickets for cement, aggregates, admixtures and additions;

— source of mixing water;

— consistence of the concrete;

— density of the fresh concrete;

— water/cement ratio of fresh concrete;

— added water content of fresh concrete;

— cement content;

— date and time when test specimens were taken;

— number of test specimens;

— time schedule of particular working steps during placing and curing of the concrete;

— temperature and weather conditions during placing and curing of the concrete;

— structural member in which a certain batch was used.

Additional information in the case of ready mixed concrete:

— name of the supplier;

— number of the delivery ticket.

All variations from the specified procedure concerning transport, delivery, casting, compaction and curing shall be recorded and reported to the responsible person.

Production control procedures in accordance with the provisions of this standard may be verified by an approved certification body as part of the conformity control (see 11.3.3.1).

The tests carried out in connection with the production control may, by prior agreement or according to the national standards or regulations valid in the place of use of the concrete, be taken into account for the conformity control, if such a control is required.

11.2.2 *Control of concrete*

11.2.2.1 *Control of constituent materials, equipment, production procedure and concrete properties*

The constituent materials, equipment, production procedure and the concrete shall be controlled as to their conformity with the specifications and the requirements.

The types and frequency of inspections/tests for constituent materials shall be as given in Table 14.

This table is based on the assumption that there is adequate quality control by the producers at the places where the constituent materials are produced. If not, the contractor shall check the compliance of the materials with the relevant standards.

The control of equipment shall ensure that the means available for storage, the weighing and gauging equipment, the mixer and the 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/tests are given in Table 15.

The checks on whether the production process is suitable and correctly carried out and whether the concrete conforms to the requirements of this standard and to any requirements specified under clause 8 shall be made as given in Table 16.

11.2.2.2 *Concrete control by the contractor when using ready mixed concrete*

When the contractor uses ready mixed concrete he shall carry out the concrete control as laid down in Table 17. In addition he shall obtain from the ready mixed concrete producer the relevant information laid down in 8.2 or 8.3 covering designed mixes and prescribed mixes, respectively.

11.2.2.3 *Control of concrete in a continuous production process (ready mixed concrete producer or prefabricated concrete manufacturer)*

The ready mixed concrete producer or the manufacturer of prefabricated concrete members shall carry out the inspection and tests as laid down in Table 14, Table 15 and Table 16.

If in a continuous production process more than one type of concrete is produced the minimum frequency of testing compressive strength shall be determined on the basis of families of mixes.

Concretes may be regarded as being in the same family if they are made with cement of the same type and strength class and from a single source and aggregate of the same geological origin and type (e.g. crushed or uncrushed). If admixtures or additions are used these may form separate families.

Relationships shall be established and documented between the relevant properties of the concrete mix within the family.

Sampling shall be carried out across the whole range of mixes produced within the family.

11.2.3 ***Inspection prior to concreting***

Before casting operations start, inspections have to be made at least on the following:

— geometry of formwork and the position of the reinforcement;

— removal of dust, sawdust, snow and ice and remains of tie wire from the formwork or sub-base;

— treatment of the hardened faces of the construction joints;

— wetting formwork and/or sub-base;

— stability of formwork;

— inspection openings;

— tightness of parts of the formwork to avoid leakage of cement paste;

— preparation of the surface of formwork;

— cleanness of reinforcement from surface deposits impairing bond (e.g. form oil, ice, paint, loose rust);

— fixtures (location, stability, cleanness);

— availability of efficient transport, means of compaction and curing appropriate to the specified consistence of the concrete;

— availability of competent personnel.

Table 14 — Materials control

	Material	Inspection/Test	Purpose	Minimum frequency
1	Cements[a]	Inspection of delivery ticket	To ascertain if the consignment is as ordered[b] and from the correct source	Each delivery
2		Inspection of delivery ticket	To ascertain if the consignment is as ordered and from the correct source	Each delivery
3		Inspection of consignment	For comparison with normal appearance with respect to grading, shape and impurities	Each delivery
4	Aggregates[c]	Test by sieve analysis	To assess compliance with standard or other agreed grading	i) First delivery from new source ii)In case of doubt following visual inspection iii) Periodically depending on local or delivery conditions
5		Tests for impurities	To assess the presence and quantity of impurities	i) First delivery from new source ii) In case of doubt following visual inspection iii) Periodically depending on local or delivery conditions
6	Additional control for light- or heavy- weight concrete	Test according to ISO 6782	To measure the bulk density	i) First delivery from new source ii) In case of doubt following visual inspection iii) Periodically depending on local or delivery conditions
7		Inspection of delivery ticket and label on container	To ascertain if the consignment is as ordered and properly marked	Each delivery
8	Admixtures[d]	Inspection of the admixture	For comparison with normal appearance	i) Each delivery ii) While in use
9		Test for density	For comparison with nominal density	In case of doubt
10	Additions[d] (bulk powders)	Inspection of delivery ticket	To ascertain if the consignment is as ordered and from the correct source	Each delivery
11	Additions in suspension	Inspection of delivery ticket	To ascertain if the consignment is as ordered and from the correct source	Each delivery
12		Test for density	To ascertain uniformity	Each delivery

[a] It is recommended that samples are taken and stored once per week and per type of cement for testing in case of doubt. For sampling see EN 196-7.

[b] At the delivery at least the type, origin and strength class are to be given on the delivery ticket.

[c] The delivery ticket should also contain information on the maximum soluble chloride content, unless the chloride content is restricted by standards and regulations which are referred to. The delivery ticket should identify possible susceptibility to alkali-silica reaction where relevant.

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

Table 14 — Materials control

	Material	Inspection/Test	Purpose	Minimum frequency
13	Water	Test by chemical analysis	To ascertain that the water is free from harmful constituents	Only if water is not taken from public supply; when new source is used for first time; and in case of doubt
14		Test by making concrete or mortar specimens according to ISO 2736	To compare setting and strength with control specimen made with water of known suitability	Only if water is not taken from public supply; when new source is used for first time; and in case of doubt

Table 15 — Equipment control

	Equipment	Inspection/Test	Purpose	Minimum frequency
1	Stockpiles, bins, etc.	Visual inspection	To ascertain conformity with requirements	Once per week
2	Weighing equipment	Visual inspection of performance	To ascertain that the weighing equipment is functioning correctly	Daily
3		Test of weighing accuracy	To ascertain the accuracy according to Table 10	i) On installation ii) Periodically depending on national regulations
4	Admixture dispensers	Visual inspection of performance	To ascertain that the dispenser is in a clean condition and functions correctly	First batch of the day for each admixture
5		Test of accuracy	To avoid inaccurate dispensing	i) On installation ii) Monthly after installation iii) In case of doubt
6	Water meter	Comparison of the actual amount with the reading on the meter	To ascertain accuracy according to Table 10	i) On installation ii) Monthly after installation iii) In case of doubt
7	Equipment for continuous measurement of water content of fine aggregates	Comparison of the actual amount with the reading on the meter	To ascertain accuracy	i) On installation ii) Monthly after installation iii) In case of doubt
8	Batching system	Comparison of the actual mass of the constituents in the batch with the intended mass by a suitable method depending on the batching system	To ascertain batching accuracy according to Table 11	i) On first installation ii) In case of doubt at subsequent installations iii) Monthly after installation
9		Visual inspection	To ascertain that the batching equipment is functioning correctly	Daily
10	Testing apparatus	Tests according to standards or other regulations	To check the conformity	Regularly depending on apparatus, however at least every 2 years
11	Mixers (including truck mixers)	Visual inspection	To check the wear of the mixing equipment	Monthly

Table 16 — Control of production procedure and of concrete properties

	Type of test	Inspection/Test	Purpose	Minimum frequency
1	Mix proportions for designed mix	Initial test	To provide proof that specified properties are met with an adequate margin	Before using a new mix if data on long term experience are not available
2	Chloride content of the mix	Initial determination (see 11.3.12)	To ensure that the maximum chloride content is not exceeded	Initial test and in case of a change in the chloride content of the constituents
3	Water content of coarse aggregates	Drying test or equivalent	To determine the supplementary water addition	If not continuous, daily. Depending on local and weather conditions more or less frequent tests may be required
4	Water content of fine aggregates	Continuous measuring system, drying test or equivalent	To determine the supplementary water addition	If not continuous, daily. Depending on local and weather conditions more or less frequent tests may be required
5	Consistence of concrete	Visual inspection	For comparison with normal appearance	Each batch or load
6		Consistence test according to ISO 4109 or ISO 4110 or ISO 4111 or ISO 9812	To assess conformity with required class of consistence and to check possible changes of water content	i) When making specimens for testing hardened concrete ii) When testing air content iii) In case of doubt following visual inspections
7	Density of fresh concrete	Density test according to ISO 6276	For supervision of batching and density control of light-weight or heavy-weight concrete	As frequently as for compressive strength test
8	Compressive strength test on moulded concrete specimen	Test according to ISO 4012	To assess the strength properties of the mix	As frequently as needed for conformity control, see 11.3, but not less than indicated in Table 18
9	Apparent density of hardened light-or heavy-weight concrete	Test according to ISO 4012	To assess specified density	As frequently as compressive strength tests
10	Added water content of fresh concrete	Record of the quantity of water added[a]	To provide data for the water/cement ratio	Every batch
11	Cement content of fresh concrete	Record of the quantity of cement added[a]	To check the cement content and to provide data for the water/cement ratio	Every batch
12	Additions content of fresh concrete	Record the quantity of additions added[a]	To check the additions content	Every batch

[a] This information may be provided by reference to the catalogue of concrete mixes in accordance with 10.3.1 or with recorded mixing instruction in accordance with 9.2.

Table 16 — Control of production procedure and of concrete properties

	Type of test	Inspection/Test	Purpose	Minimum frequency
13	Water/cement ratio of fresh concrete[a]	By dividing (3) + (4) + (10) by (11) or by test methods which have to be agreed upon	To assess specified water/cement ratio	Daily or more frequently as required.
14	Air content of fresh concrete mixes with specified air content	Test according to ISO 4848	To assess conformity with the prescribed content of entrained air	For mixes with entrained air content: i) first batch at least daily ii) more frequently depending on the conditions of production and environmental influences
15	Uniformity	Test by comparing the properties of sub-samples taken from different parts of a batch	To assess uniformity of the mix	In case of doubt
16	Water penetration	Test according to ISO 7031	To assess water penetration resistance	At initial testing, subsequent frequency to be agreed upon
17	Other characteristics	In accordance with relevant standards or to be agreed upon	To assess conformity with the required characteristics	To be agreed upon

[a] But see Table 3, footnote 2.

Table 17 — Concrete control by contractor when using ready mixed concrete

Subject		Inspection/Test	Purpose	Minimum frequency
1	Delivery ticket	Visual inspection	To ascertain that delivery corresponds to the specification[a]	Each delivery
2	Consistence of concrete	Visual inspection	For comparison with normal appearance	Each delivery
3		Consistence test according to ISO 4109 or ISO 4110 or ISO 4111 or ISO 9812	To assess conformity with required consistence class	i) When making specimens for testing hardened concrete ii) In case of doubt following visual inspection
4	Uniformity of concrete	Visual inspection	For comparison with normal appearance	Each delivery
5		Tests by comparing the properties of sub-samples taken from different parts of a batch	To assess uniformity of the mix	In case of doubt following visual inspection
6	Concrete appearance in general	Visual inspection	For comparison with normal appearance, e.g. colour	Each delivery
7	Production control of supplier of concrete	Check of certificate of approved certification body that production is controlled; otherwise inspection of ready mixed plant	To ascertain that production control is carried out	i) First contract with new supplier ii) In case of doubt
8	Compressive strength of concrete sampled on site	Test according to ISO 4012	To assess the strength properties of the mix	As frequently as needed for conformity control, see 11.3
9	Air content of fresh concrete mixes with specified air content	Test according to ISO 4848 on site	To assess conformity with required air content	i) As frequently as needed for conformity control ii) at least daily or more frequently depending on the environmental influences iii) in case of doubt
10	Other characteristics	In accordance with relevant standards or to be agreed upon	To assess conformity with the required characteristics	To be agreed upon

[a] See clause 8.

11.2.4 *Inspection during transport, placing, compacting and curing of fresh concrete*

During casting operations inspections have to be made at least on the following:

— maintenance of uniformity of the concrete during transport and placing;

— uniform distribution of the concrete in the formwork;

— uniform compaction and avoidance of segregation during compaction;

— maximum height the concrete is allowed to drop freely;

— depth of layers;

— rate of casting and rise of the concrete in the form in relation to the specified pressure on the formwork;

— time between mixing or delivery of concrete and casting in relation to the specified time;

— special measures in the case of cold weather or hot weather concreting;

— special measures under extreme weather conditions, such as heavy rainfall;

— places where construction joints are made;

— treatment of construction joints before hardening;

— finishing operations in relation to the specified finish;

— method of casting and curing time in relation to the ambient conditions and the strength development;

— avoidance of damage by vibrations or shocks of the freshly cast concrete.

11.3 Conformity control

11.3.1 *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 a lot, defined in advance, with the specifications.

11.3.2 *Conformity criteria*

The conformity or non-conformity is judged on the basis of the conformity criteria. Conformity leads to acceptance while non-conformity may lead to further action.

The inspection, sampling, lot sizes and conformity criteria shall comply with the procedures given in 11.3.3 to 11.3.12. For properties not covered in these clauses conformity criteria shall be agreed upon, account being taken of the verification system and the intended level of reliability of the concrete structure or component considered.

If the results of tests on moulded specimens do not fulfil the conformity requirements or are not available or if defects of workmanship or influence of extreme weather conditions, (e.g. frost) give rise to doubt as to strength, durability and the safety of the structure, supplementary testing according to ISO 7034 on cores taken from the finished structure may be required or a combination of tests on cores and non-destructive tests on the finished structure, e.g. according to ISO 8045, ISO 8046 or ISO 8047 may be carried out.

11.3.3 *Verification systems*

Conformity control for ready mixed concrete plants, plants for manufacturing prefabricated elements and sites shall be verified by one of the following systems.

11.3.3.1 *Case 1: verification by a third party*

Verification of conformity is carried out by an approved certification body, e.g. as defined in EN 45011 to verify that the production is under production control according to 11.2 and that the results of the production control tests comply with the required properties of the concrete (see 11.3.5 to 11.3.11).

As part of this verification the approved certification body may test samples taken by itself from the running production in order to check the results of the production control.

11.3.3.2 *Case 2: verification by the client*

In cases where an approved certification system does not exist, verification shall be carried out by the client or his representative using appropriately qualified personnel. It has to be verified that the production control tests are appropriate to the required properties of the concrete (see 11.3.5 to 11.3.11). As part of this verification the client may test samples taken by himself from the production in order to check the results of the production control.

This case may also be applied — even though there exists an approved certification system but (one) which is not applied to the concrete in question — to site mixed concrete structures where the risk of life and economic consequences are small or negligible and for concrete grades not higher than C20/25.

11.3.3.3 *Acceptance testing*

Even if there is a third party (case 1) acceptance testing may be intended by the client. In this case sampling for acceptance testing shall be by agreement.

11.3.4 ***Sampling responsibility***

The responsibility (producer, contractor, client or third party) for the sampling depends on the national standards or regulations valid in the place of use of the concrete.

11.3.5 ***Sampling plan and conformity criteria for compressive strength of concrete***

11.3.5.1 *Sampling plan and conformity criteria for concrete placed at an individual site*

11.3.5.1.1 *General*

Conformity verification according to this clause should be the basis for the contract between the contractor and the client (authority respectively).

For judging the conformity of concrete strength, the quantity of concrete used for a structure, structural component, etc. is to be subdivided into lots on which conformity is judged. The total volume of concrete for one lot shall be produced under conditions which are deemed to be uniform (same family as defined in **11.2.2.3**). The size of a lot shall be:

— 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;

— but in no case more than 450 m^3 or more than the production of one weeks casting, whichever is less.

In case of acceptance testing by the client (**11.3.3.3**) the lot shall be defined by the client.

11.3.5.1.2 *Sampling plan and conformity criteria in the case of using site mixed concrete*

For each lot at least 6 independent (separately taken) samples shall be taken. If it is intended to take more than 6 samples per lot this has to be agreed upon before starting the production of concrete.

In the case where concrete of lower strength classes up to C20/25 and smaller lots up to 150 m^3 are to be judged, 3 independent (separately taken) samples may be taken.

Conformity is assumed if test results satisfy

— criterion 1 (of **11.3.5.4**) in the case of 6 or more samples;

— criterion 2 (of **11.3.5.4**) in the case of 3 samples.

Where the national standards or regulations, valid in the place of use of the concrete, allow to do so, a declaration of conformity by the producer according to EN 45014 may be sufficient, provided that

— there is a production control complying with the requirements;

— previous tests gave sufficient results;

— the required concrete strength class is not higher than C20/25;

— lots are smaller than 150 m^3 or concrete components are of less importance for the safety of the structure.

11.3.5.1.3 *Sampling plan and conformity criteria in the case of using ready mixed concrete at site*

For the sampling plan and conformity criteria in the case where ready mixed concrete is used (at site) two options are applicable. The option to be used depends on the national standards or regulations valid in the place of use of the concrete or, if such regulations do not exist, on agreement.

Option 1: *Conformity based on sampling by lots*

The same sampling plan and conformity criteria as stated under **11.3.5.1.2** have to be applied. Sampling shall always be done on site.

Where the conformity of the ready mixed concrete delivered has already been verified by a third party (case 1, **11.3.3.1**) and where the verification has been based on at least 15 test results, then for the verification of conformity on the site

— the value $\lambda = 1{,}48$ may be taken for any number of samples $n \geq 6$ by using criterion 1 of **11.3.5.4**;

— in the case of three samples by using criterion 2 the strength shall satisfy the following conditions:

$\bar{x}_3 \geq f_{ck} + 3$[14)]

$x_{min} \geq f_{ck} - 1$[14)]

Option 2: *Conformity based on approved certification of the concrete*

At the individual site no sampling and conformity testing is necessary, provided

— the conformity of the ready mixed concrete delivered is verified by an approved certification body in accordance with **11.3.5.4**;

— satisfactory test results of samples taken from the running production and samples at a site are available from the ready mix supplier, taken on the same concrete family within the last 7 days of production.

[14)] For symbols see **11.3.5.4**.

11.3.5.2 *Sampling plan and conformity criteria for continuous production of concrete in ready mixed concrete plants*

Conformity verification according to this clause should be the basis for the contract between the ready mix concrete producer and the contractor.

Sampling shall be carried out on each family of concrete (see **11.2.2.3**) produced under conditions which are deemed to be uniform on the total volume or time of the concrete production according to Table 18 whichever gives the higher number of samples.

Table 18 — Number of samples for conformity control

Strength class	Number of samples	
≤ C20/25	1/150 m^3, but not more than 6 samples/day unless otherwise specified	1/day
> C20/25	1/75 m^3, but not more than 15 samples/day unless otherwise specified	

Conformity is assumed if the test results satisfy the requirements of criterion 1.

If more than 15 test results during the production of one type or one family of concrete are satisfactory, only the last 15 results have to be taken into account.

11.3.5.3 *Sampling plan and conformity criteria for continuous production of concrete in plants for manufacturing prefabricated elements*

Conformity verification according to this clause should be the basis for the contract between the element producer and the contractor or the client respectively.

The sampling plan and conformity criteria of **11.3.5.2** shall apply, provided the element plant is operated under the certification scheme of an approved certification body; in other cases **11.3.5.1** shall apply.

11.3.5.4 *Conformity criteria for compressive strength*

Criterion 1

This criterion applies where conformity is checked by considering the results of 6 or more consecutive samples the strengths of which are $x_1, x_2, \ldots x_n$.

The strength of a sample shall be the test result from one specimen or the average of the results when two or more specimens are made from one sample.

The strength shall satisfy the following conditions:

$$\bar{x}_n \geq f_{ck} + \lambda s_n$$

$$x_{min} \geq f_{ck} - k$$

where

x_{min} is the lowest individual value of the set of samples;

$\bar{x}_n$ is the mean strength of the set of samples;

s_n is the standard deviation of the set of strength results from the samples;

f_{ck} is the specified characteristic strength of the concrete;

λ and k are values to be taken from Table 19 according to the number of samples in the set.

Table 19

n	λ	k
6	1,87	3
7	1,77	3
8	1,72	3
9	1,67	3
10	1,62	4
11	1,58	4
12	1,55	4
13	1,52	4
14	1,50	4
15	1,48	4

Criterion 2

This criterion applies where conformity is checked by considering the results of three samples the strengths of which are x_1, x_2 and x_3.

The strength of a sample shall be the test result from one specimen or the average of the results when two or more specimens are made from one sample.

The strength shall satisfy the following conditions:

$$\bar{x}_3 \geq f_{ck} + 5$$

$$x_{min} \geq f_{ck} - 1$$

where

$\bar{x}_3$ is the mean strength value of the three samples.

11.3.6 ***Sampling plan and conformity criteria for consistence of concrete***

Visual inspection shall be made on each batch or load or, in case of ready mixed concrete, on each delivery. If the concrete has a normal appearance compared with the specified consistence it may be deemed to comply.

Where a sample for consistence testing is to be taken it shall be representative of the batch, load or delivery.

Conformity is assumed if the consistence is within the specified consistence class, unless otherwise specified.

11.3.7 ***Sampling plan and conformity criteria for density of light-weight concrete***

The frequency of sampling shall be as for compressive strength.

Conformity is assumed, if the mean value of oven dry density lies within the specified range of the density classes (Table 9).

11.3.8 ***Sampling plan and conformity criteria for water/cement ratio***

At least one determination of the w/c ratio shall be made per casting day. The results of the production control in accordance with Table 16 may be accepted. However samples shall be taken in case of doubt.

Conformity is assumed, if the mean value of water/cement ratio is not higher than the specified value and if the single values do not exceed the specified value by more than 0,02.

The concrete can be deemed to conform with the requirements for maximum water/cement ratio if it conforms with the relevant concrete strength class depending on the cement strength class given in Table 20. Table 20 does not apply if additions of type II or air entraining agents are used.

Other relationships than given in Table 20 may be necessary, e.g. according to the aggregates used. The relationships may be applied if they are confirmed by testing and documented.

11.3.9 ***Sampling plan and conformity criteria for cement content***

The frequency of sampling or determination shall be agreed upon.

Conformity is assumed if the mean value of the cement content is equal to or higher than the specified value. Single values may be lower, but not lower than 5 % by weight of the specified value.

11.3.10 ***Sampling plan and conformity criteria for air content of fresh concrete***

The frequency of sampling shall be at least once a day or once per 150 m^3, whichever is more frequent. Conformity is assumed if every value from individual samples is higher than the specified value, but not more than 3 % above the specified value unless otherwise specified.

11.3.11 ***Sampling plan and conformity criteria for water penetration***

The frequency of sampling and testing shall be agreed upon.

Conformity is assumed if the maximum value and mean value of the penetration front of each specimen is equal to or smaller than the values given in **7.3.1.5**.

Results of production control in accordance with Table 16 may be accepted.

11.3.12 ***Sampling plan and conformity criteria for chloride content***

The frequency and method of determination shall be agreed upon.

Suitable methods include

a) calculations based upon measured chloride contents of the constituents;

b) calculations based upon the nominal maximum chloride contents of the constituents;

c) tests of fresh concrete for chloride content.

The values obtained shall not exceed the maximum values given in **5.5**.

The determination shall be made for each mix design and shall be repeated if there is a change in the chloride content of any of the constituents.

Table 20 — Strength classes of concrete related to w/c ratio

Strength class of cement	Water/cement ratio				
	0,65	0,60	0,55	0,50	0,45
CE 32,5	C20/25	C25/30	C30/37	C35/45	C40/50
CE 42,5	C25/30	C30/37	C35/45	C40/50	C45/55

Annex A Modifications to reference documents

A.1 ISO 1920 Test specimens; dimensions; tolerances

Clause 2: Add at the end of 2nd paragraph: "The full range of sizes and types of specimens will not be available in all countries."

A.2 ISO 2736-2 Making and curing of test specimens for strength tests

Clause 3.2: Delete "(optional)" in heading; introduce 2nd paragraph: "In case of doubt values obtained from tests by use of a filling frame shall be considered to be relevant."

Clause 5.1: Insert in 2nd paragraph: "A filling frame shall be used for specimens compacted by vibration [according to 3.3 a) and 3.3 b)]. The height of the concrete in the filling frame after compaction shall not exceed 10 % of the specimen height."

Clause 5.2.1: Add "When using highly fluent concrete (slump S4 or Vebe V4), it may be necessary to adapt the method of compaction to the consistence of the concrete."

Clause 6: Include an indication of the time of curing (period between casting and testing).

A.3 ISO 4012 Compressive strength

Clause 2: Indicate more precisely: "ISO 2736-1 and ISO 2736-2."

Clause 6: After 5th paragraph: "The loading rate should be chosen in such a way that the whole test lasts about 60 s." Instead of 6th paragraph: "Continue loading until failure of the specimen with the chosen loading rate and note the maximum load."

Clause 7: Add "Ig nore ISO 1920 clause 5 and base the expression of test results on actual dimensions of the test specimen to the nearest mm."

A.4 ISO 4013 Flexural strength

Clause 6, 2nd paragraph: Instead of "Once adjusted. ..." introduce: "The loading rate should be chosen in such a way that the whole test lasts about 60 s. Continue loading until failure of the specimen with the chosen loading rate and note the maximum load."

A.5 ISO 7031 Resistance to water penetration

Clause 4, 2nd paragraph: Instead of the reference to ISO 2736-1 it shall read: "The specimen shall be cured and stored under water until testing."