



BSI Standards Publication

Common rules for precast concrete products

National foreword

This British Standard is the UK implementation of EN 13369:2023. It supersedes BS EN 13369:2018, which is withdrawn.

The UK participation in its preparation was entrusted to Technical Committee B/524, Precast concrete products.

A list of organizations represented on this committee can be obtained on request to its committee manager.

EN 13369:2023 and the respective European product standards contain provisions for specific precast products related to design, detailing, tolerances and production which the designer should consider. For products to be used in the UK, matters relating to design should respect decisions made in the UK National Annex to the relevant Eurocode.

Reference is made to “other provisions valid in the place of use”. In the following subclauses, provisions valid in the UK are noted.

- 4.1.3 – Characteristics of reinforcing steel should be determined in accordance with BS 4449, BS 4483, BS 4482 and BS 8666.
- 4.1.4 – Characteristics of prestressing steel should be determined in accordance with BS 5896 and BS 4486.
- 4.2.1.1 – EN 206 is accompanied in the UK by the complementary British Standards BS 8500-1, *Concrete – Complementary British Standard to BS EN 206 – Part 1: Method of specifying and guidance for the specifier* and BS 8500-2, *Concrete – Complementary British Standard to BS EN 206 – Part 2: Specification for constituent materials and concrete*.

NOTE: EN 206 is referred to in various other clauses; where this occurs, users are encouraged to refer to BS 8500-1 and/or BS 8500-2 for details on how EN 206 may be implemented in the UK.

Annex A contains guidance on exposure classes and the minimum concrete cover to reinforcement for precast concrete products. For concrete exposed to environmental conditions in the UK, there is guidance on the quality of concrete and minimum recommended cover for durability, for all conditions, in Annex A of BS 8500-1:2015+A1:2016, *Concrete – Complementary British Standard to BS EN 206 – Part 1: Method of specifying and guidance for the specifier*.

For particular applications, the UK committee recommends users refer to the following standards.

For agricultural buildings:

- BS 5502-21:1990, *Buildings and structures for agriculture — Part 21: Code of practice for selection and use of construction materials*
- BS 5502-22:2003+A1:2013, *Buildings and structures for agriculture — Part 22: Code of practice for design, construction and loading*

For maritime works:

- BS 6349-1-4:2021, *Maritime works – Part 1-4: General – Code of practice for materials*

In informative Annex C, Clauses C.1 to C.4 provide methods to reduce the material safety factors. These are broadly aligned with Annex A

of EN 1992-1-1:2004+A1:2014, which the UK committee advises takes precedence. In particular where direct structural strength is used when declaring the potential strength (including via Annex B), a reduction in γ_c is included implicitly in the conversion factor η (4.2.2.2.5) and no further reduction in γ_c is recommended (see PD 6687-1, *Background paper to the National Annexes to BS EN 1992-1, BS EN 1992-3 and BS EN 1992-4*).

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English Version

Common rules for precast concrete products

Règles communes pour les produits préfabriqués en
béton

Allgemeine Regeln für Betonfertigteile

This European Standard was approved by CEN on 28 August 2023.

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

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European foreword

This document (EN 13369:2023) has been prepared by Technical Committee CEN/TC 229 “Precast concrete products”, the secretariat of which is held by AFNOR.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by May 2024 and conflicting national standards shall be withdrawn at the latest by May 2024.

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

This document supersedes EN 13369:2018.

The main changes compared to the previous edition are listed below:

- a) normative references have been updated taking into account the amendment A2 of EN 206;
- b) the specifications regarding the concrete strength at the end of curing were revised;
- c) Annex A was revised with the deletion of environmental conditions classes;
- d) the vocabulary in Annex D was revised to comply with the Construction Product Regulation;
- e) Annex H on prestressing losses was revised;
- f) an informative Annex related to the performance-based approach was added.

EN 13369 is a common reference for the following group of specific product standards prepared by Technical Committee CEN/TC 229:

- EN 1168, *Precast concrete products — Hollow core slabs*;
- EN 12737, *Precast concrete products — Floor slats for livestock*;
- EN 12794, *Precast concrete products — Foundation piles*;
- EN 12839, *Precast concrete products — Elements for fences*;
- EN 12843, *Precast concrete products — Masts and poles*;
- EN 13198, *Precast concrete products — Street furniture and garden products*;
- EN 13224, *Precast concrete products — Ribbed floor elements*;
- EN 13225, *Precast concrete products — Linear structural elements*;
- EN 13693, *Precast concrete products — Special roof elements*;
- EN 13747, *Precast concrete products — Floor plates for floor systems*;
- EN 13748-1, *Terrazzo tiles — Part 1: Terrazzo tiles for internal use*;
- EN 13748-2, *Terrazzo tiles — Part 2: Terrazzo tiles for external use*;

- EN 13978-1, *Precast concrete products — Precast concrete garages — Part 1: Requirements for reinforced garages monolithic or consisting of single sections with room dimensions*;
- EN 14843, *Precast concrete products — Stairs*;
- EN 14844, *Precast concrete products — Box culverts*;
- EN 14991, *Precast concrete products — Foundation elements*;
- EN 14992, *Precast concrete products — Wall elements*;
- EN 15037-1, *Precast concrete products — Beam-and-block floor systems — Part 1: Beams*;
- EN 15037-2, *Precast concrete products — Beam-and-block floor systems — Part 2: Concrete blocks*;
- EN 15037-3, *Precast concrete products — Beam-and-block floor systems — Part 3: Clay blocks*;
- EN 15037-4, *Precast concrete products — Beam-and-block floor systems — Part 4: Expanded polystyrene blocks*;
- EN 15037-5, *Precast concrete products — Beam-and-block floor systems — Part 5: Lightweight blocks for simple formwork*;
- EN 15050, *Precast concrete products — Bridge elements*;
- EN 15258, *Precast concrete products — Retaining wall elements*;
- EN 15435, *Precast concrete products — Normal weight and lightweight concrete shuttering blocks — product properties and performances*;
- EN 15498, *Precast concrete products — Wood-chip concrete shuttering blocks — Product properties and performances*.

Any feedback and questions on this document should be directed to the users' national standards body. A complete listing of these bodies can be found on the CEN website.

According to the CEN-CENELEC Internal Regulations, the national standards organizations of the following countries are bound to implement this European Standard: Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Republic of North Macedonia, Romania, Serbia, Slovakia, Slovenia, Spain, Sweden, Switzerland, Türkiye and the United Kingdom.

Introduction

This document is intended to outline the general common specifications applicable to a large variety of precast concrete products manufactured in a factory environment. It acts as a reference standard for other standards to enable a more consistent approach to standardization in the field of precast concrete products and to reduce the variations brought about by a large number of standards produced in parallel by different groups of experts. At the same time, it allows those experts the flexibility to include variations in specific product standards where they are required.

This document has been produced as part of the total CEN programme for construction and refers to the relevant specifications of associated standards EN 206 for concrete and the EN 1992 series for the design of concrete structures. The installation of some precast concrete products is dealt with by EN 13670.

As it is not a harmonized standard, it is not allowed to be used on its own for the purpose of CE marking of precast concrete products.

The design of precast concrete products should be verified to ensure the fitness of their properties for the particular application, particular attention being paid to design co-ordination with other parts of the construction.

1 Scope

This document provides the specifications, the basic performance criteria and the Assessment and Verification of Constancy of Performance (AVCP) for unreinforced, reinforced and prestressed precast concrete products made of compact light-, normal- and heavyweight concrete according to EN 206 with no appreciable amount of entrapped air other than entrained air. Concrete containing fibres for other than mechanical properties (steel, polymer or other fibres) is also covered. It does not cover precast reinforced components of lightweight aggregate concrete with open structure nor glass-fibre reinforced concrete.

It can also be used to specify products for which there is no standard. Not all of the specifications (Clause 4) of this document are relevant to all precast concrete products.

Some European product standards refer to this document. They can include specific provisions that take precedence over the provisions of this document.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

EN 206:2013+A2:2021, *Concrete - Specification, performance, production and conformity*

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

EN 1008, *Mixing water for concrete - Specification for sampling, testing and assessing the suitability of water, including water recovered from processes in the concrete industry, as mixing water for concrete*

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

EN 1992-1-1:2004,¹ *Eurocode 2: Design of concrete structures - Part 1-1: General rules and rules for buildings*

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

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

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

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

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

EN 12350-8, *Testing fresh concrete - Part 8: Self-compacting concrete - Slump-flow test*

EN 12350-9, *Testing fresh concrete - Part 9: Self-compacting concrete - V-funnel test*

EN 12350-10, *Testing fresh concrete - Part 10: Self-compacting concrete - L box test*

EN 12350-11, *Testing fresh concrete - Part 11: Self-compacting concrete - Sieve segregation test*

¹ As impacted by EN 1992-1-1:2004/AC:2010 and EN 1992-1-1:2004/A1:2014.

EN 12350-12, *Testing fresh concrete - Part 12: Self-compacting concrete - J-ring test*

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

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

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

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

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

EN 13501-1, *Fire classification of construction products and building elements - Part 1: Classification using data from reaction to fire tests*

EN ISO 717-1, *Acoustics - Rating of sound insulation in buildings and of building elements - Part 1: Airborne sound insulation (ISO 717-1)*

EN ISO 717-2, *Acoustics - Rating of sound insulation in buildings and of building elements - Part 2: Impact sound insulation (ISO 717-2)*

EN ISO 10456, *Building materials and products - Hygrothermal properties - Tabulated design values and procedures for determining declared and design thermal values (ISO 10456)*

ASTM C173/C173M - 10b, *Standard Test Method for Air Content of Freshly Mixed Concrete by the Volumetric Method*

3 Terms and definitions

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

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

- ISO Online browsing platform: available at <https://www.iso.org/obp/>
- IEC Electropedia: available at <https://www.electropedia.org/>

3.1 General

3.1.1

precast concrete product

product which is made of concrete and is manufactured in accordance with this document or a specific product standard in a place different from the final destination of use, protected from adverse weather conditions during production and which is the result of an industrial process under a factory production control system and with the possibility of sorting before delivery

Note 1 to entry: In relevant European Standards, the shorter term “Precast product” is often used.

3.1.2

concrete cover

distance between the surface of the reinforcement closest to the nearest concrete surface (including links and stirrups and surface reinforcement where relevant) and the nearest concrete surface

[SOURCE: EN 1992-1-1:2004]

3.1.3

concrete family

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

[SOURCE: EN 206:2013+A2:2021, 3.1.1.2]

3.1.4

tendon

prestressing unit (wire, strand or bar) subjected to pre-tensioning

3.1.5

lightweight concrete

concrete with a closed structure and with an oven-dry density of 800 kg/m³ to 2 000 kg/m³

3.1.6

normal weight concrete

concrete with an oven-dry density of 2 000 kg/m³ to 2 600 kg/m³

3.1.7

heavyweight concrete

concrete with an oven-dry density of more than 2 600 kg/m³

3.1.8

product-type

set of representative performance levels or classes of construction product, in relation to its characteristics, produced using a given combination of raw materials or other elements in a specific production process

3.1.9

reclaimed crushed aggregate

aggregate gained by crushing hardened concrete that has not been previously used in construction

[SOURCE: EN 206:2013+A2:2021]

3.1.10

recycled aggregate

aggregate resulting from the processing of inorganic material previously used in construction

[SOURCE: EN 206:2013+A2:2021]

3.2 Dimensions

3.2.1

principal dimensions

length, width, depth or thickness

3.2.2

nominal dimension

dimension declared in the technical documentation and targeted at manufacture

3.3 Tolerances

3.3.1

tolerance

sum of the absolute values of the upper and the lower permitted deviation

3.3.2

deviation

difference between an actual measure and the corresponding nominal dimension

3.4 Durability

3.4.1

durability

ability of a precast concrete product to satisfy, with anticipated maintenance, the design performance requirements during its design working life under the influence of the expected environmental actions

3.4.2

design working life

assumed period for which a structure or part of it is to be used for its intended purpose with anticipated maintenance but without major repair being necessary

3.4.3

environmental conditions

physical or chemical impacts to which the precast concrete product is exposed and which result in effects on the concrete or reinforcement or embedded metal that are not considered as loads in structural design

3.4.4

ambient conditions

hygrothermic conditions in the factory which result in effects on the hardening process of the concrete

3.5 Mechanical properties

3.5.1

potential strength

compressive concrete strength derived from tests on cubes or cylinders moulded and cured in laboratory conditions in accordance with EN 12390-2

3.5.2

structural strength

compressive concrete strength derived from tests on specimens (drilled cores or cut prisms) taken from the precast concrete product (direct structural strength) or derived from tests on moulded specimens cured in the same ambient conditions as the product itself (indirect structural strength)

3.5.3

characteristic strength

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

4 Specifications

4.1 Material and components specifications

4.1.1 General

Only materials with established suitability shall be used.

For a particular material, the establishment of suitability may be based on a European Standard which refers specifically to the use of this material in concrete or in precast concrete products; in absence of a European Standard, it may also result, under the same conditions, from an ISO Standard.

Where this material is not covered by a European or ISO Standard, or if it deviates from the specifications of these standards, the establishment of suitability may be based on:

- the provisions valid in the place of use of the precast concrete product which refer specifically to the use of this material in concrete or in precast concrete products; or
- a European Technical Assessment specifically for the use of this material in concrete or precast concrete products.

4.1.2 Constituent materials of concrete

4.1.2.1 General

EN 206:2013+A2:2021, 5.1 shall apply. When relevant, the following additional provisions may be used.

4.1.2.2 Reclaimed crushed aggregates and recycled coarse aggregates

4.1.2.2.1 General

Reclaimed crushed aggregates and recycled aggregates to be used for concrete, mixed with or without natural aggregates, shall not adversely alter the rate of setting and hardening of concrete, nor shall it be detrimental to the durability of the precast concrete product in the end-use conditions.

NOTE Other provisions valid in the place of use can apply.

4.1.2.2.2 Reclaimed aggregates

Reclaimed aggregates may be used for concrete provided it is only used internally by the manufacturer. They shall not be added in quantities greater than 5 % by mass of the total aggregate if they aren't properly separated in function of their particle size.

Reclaimed aggregates may be used up to 20 % as coarse aggregates and up to 10 % as fine aggregates provided that:

- a) they come from a concrete with strength class at least equal to the required strength class of the new concrete product;
- b) they are properly separated in function of their particle size;
- c) they are stored and handled so that their properties do not change significantly and are not subject to contamination.

Reclaimed aggregates used in higher percentages shall be treated as recycled aggregates.

4.1.2.2.3 Recycled aggregates

Fine recycled aggregates coming from an external source shall not be used.

Coarse recycled aggregates may be used following the recommendations given in EN 206:2013+A2:2021, E.3.

4.1.3 Reinforcing steel

Characteristics of reinforcing steel (bars, coils and welded fabric) can be found in EN 1992-1-1:2004, 3.2. They should be determined using EN 10080.

These characteristics may also be determined according to European Technical Assessments or provisions valid in the place of use of the product.

NOTE Recommendations on indented bars and wires are given in Annex J.

4.1.4 Prestressing steel

Characteristics of prestressing steel (wire, bars and strand) can be found in EN 1992-1-1:2004, 3.3.

They should be determined using EN 10138-1, EN 10138-2, EN 10138-3 and EN 10138-4.

These characteristics may also be determined according to European Technical Assessments or provisions valid in the place of use of the product.

4.1.5 Inserts and connectors

Mechanical inserts and connectors shall:

- a) resist the design actions;
- b) have the necessary ductility.

Permanent connecting parts and fasteners shall maintain these properties for the design working life of the precast concrete product.

Provisions valid in the place of use of the product shall be taken into account.

NOTE Recommendations for the design of some fastenings can be found in EN 1992-4; recommendations for the design of lifting and handling devices can be found in CEN/TR 15728 and verification method in EN 13155. When independently placed on the market, lifting devices are covered by Directive 2006/42/EC.

4.2 Production specifications

4.2.1 Concrete production

4.2.1.1 General

For concrete composition, type of cement, use of aggregates, additions and admixtures, and for resistance to alkali-silica reaction, chloride content, air content and concrete temperature, EN 206:2013+A2:2021, 5.2 and 5.3 shall apply.

For specification of concrete EN 206 shall apply.

NOTE When concrete is specified by the manufacturer, basic requirements (EN 206:2013+A2:2021, 6.2.2) are given in the design documentation and additional specifications (EN 206:2013+A2:2021, 6.2.3) are included only when relevant. Characteristics related to the concrete casting are not relevant for precast concrete elements.

4.2.1.2 Placing and compaction of concrete

Concrete shall be placed and compacted so as to retain no appreciable amount of entrapped air other than entrained air (e.g. to achieve sufficient frost resistance) to avoid detrimental segregation and to ensure the proper embedding of the reinforcement.

4.2.1.3 Curing (protection against drying out)

The concrete shall be protected during curing so that loss in strength and cracking due to temperature and shrinkage and that, if relevant, detrimental effects on durability, are avoided.

All surfaces of newly cast concrete may be protected by one of the methods listed in Table 1 or by any other method applicable in the place of use, unless it is shown by tests and inspection on the finished product or on representative samples, that other means are relevant in the production environment.

Table 1 — Protection against drying out

Method	Typical means of protection
A - Without addition of water	— keeping the concrete in an environment with a relative humidity above 65 % for CEM I and CEM II/A, above 75 % for all the other types of binders;
	— keeping the formwork in place;
	— covering the concrete surface with vapour-resistant sheets
B - Keep the concrete moist by addition of water	— maintaining wet coverings on the concrete surface;
	— keeping the concrete surface visibly wet by spraying with water
C - Use of curing compounds	Curing compounds used shall conform to provisions valid in the place of use

Other means than those defined in Table 1 may be employed if the value of the water absorption of the concrete, measured according to the test procedure defined in Annex F, does not exceed 10 % (in relative proportion) of the value of water absorption of the concrete complying with the specifications in Table 2. The water absorption test is run on (30 ± 1) mm thick samples that include the surface exposed to the environment.

For methods A and B, the protection shall be maintained until the compressive strength at the end of curing $f_{c,cure}$ related to the surface zone is equal to or greater than the value defined in Table 2 for the corresponding exposure class on the place of use.

NOTE Curing requirements can be subject to other provisions valid in the place of use.

For design working life of more than 50 years, or for specific local environmental conditions, other values may be given following the provisions valid in the place of use.

The measure of the mean compressive strength $f_{c,cure}$ shall be done on concrete samples that are submitted to the same protection against drying out as the product.

The degree of hardening in Table 2 may either be measured by testing a concrete sample or estimated by calculation using a hardening law based on initial type testing or the maturity concept.

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

Table 2 — Minimum $f_{c,cure}$ at the end of protection against drying out

Compressive strength class	Exposure class on the place of use		
	X0, XC1	XC2, XC3, XC4, XD1, XD2, XF1, XS1	XD3, XS2, XS3, XF2, XF3, XF4, XA1, XA2, XA3
C20/25, C25/30, C30/37	12 ^a /15 ^b	35 % of f_{ck} ^c	60 % of f_{ck} ^c
C35/45, C40/50, C45/55, C50/60, C55/67			20 ^a /25 ^b
C60/75, C70/85, C80/95, C90/105, C100/115			35 % of f_{ck} ^c
^a cylinder.			
^b cube.			
^c f_{ck} characteristic compressive strength of the concrete at the age of 28 days targeted by the manufacturer.			

4.2.1.4 Accelerated hydration by heat treatment

Where heat treatment at atmospheric pressure is applied to concrete during production in order to accelerate its hardening, it shall be demonstrated by initial testing that the required strength is achieved for each concrete family concerned.

- Depending on material and climatic conditions, more restricting specifications may apply to the heat treatment of outdoor products in certain areas according to provisions valid in the place of use. The following conditions shall be fulfilled when the maximum mean temperature T_{mean} within the concrete exceeds 40 °C during the curing process unless previous positive experience has shown that special measures are not necessary to avoid micro cracking and/or durability defects: a preheating period shall be applied during which T_{mean} does not exceeds 40 °C;
- the temperature difference between adjacent parts of the product during the heating and the cooling phases shall be limited to 20 °C.

The duration and heating rate of the full heating and cooling period (if appropriate) shall be documented.

During the full heating and cooling period T_{mean} shall be limited to the values of Table 3. However higher temperatures may be accepted provided the durability of concrete under the specified environment is demonstrated by long term positive experience.

Table 3 — Conditions for accelerated hydration

Product environments	Maximum mean concrete temperature T_{mean} ^a
Predominantly dry or moderate humidity	— $T_{mean} \leq 85$ °C ^b
Wet and cyclic wet	— $T_{mean} \leq 65$ °C
^a Individual values may be 5 °C higher. ^b When 70 °C < $T_{mean} \leq 85$ °C initial tests shall have demonstrated that the structural strength at 90 d corresponds with normal evolution of hardening with respect to the structural strength obtained at 28 days.	

For wet and cyclic wet environments, in case of no long-term positive experience, the suitability of the higher temperature treatment shall be demonstrated; the following limits may be a basis for this demonstration: for concrete: $\text{Na}_2\text{O}_{\text{eq}}$ content $\leq 3,5 \text{ kg/m}^3$, for cement SO_3 content $\leq 3,5 \%$ by mass.

The above limits for $\text{Na}_2\text{O}_{\text{eq}}$ and SO_3 content may be changed in value, or limits on other constituents may be put, according to the results of scientific or technical experience.

4.2.2 Hardened concrete

4.2.2.1 Strength classes

For compressive strength classes of concrete EN 206:2013+A2:2021, 4.3.1 applies.

For design purposes, the properties of strength classes for normal and heavy weight concrete up to C90/105 are given in EN 1992-1-1:2004, Table 3.1 and for lightweight concrete up to LC 80/88 in EN 1992-1-1:2004, Table 11.3.1.

The manufacturer may select intermediate classes, in 1,0 MPa steps of the characteristic strengths. In this case, other concrete properties are obtained by linear interpolation.

For prestressed precast concrete products, the minimum strength class of concrete shall be C30/37 for normal weight concrete and LC 16/18 for lightweight concrete, unless the manufacturer can provide technical evidence that the strength class can be lowered.

4.2.2.2 Compressive strength

4.2.2.2.1 General

The compressive strength to verify the strength class of concrete is defined by the potential strength; the manufacturer may use direct structural strength or indirect structural strength to confirm it.

4.2.2.2.2 Potential strength

The potential strength shall be tested at 28 days.

Tests of potential strength may be performed before 28 days in order to evaluate the progression of potential strength or to estimate at early age the potential strength at 28 days by an appropriate hardening law. When relevant, tests may be performed at an age greater than 28 days.

For determination of potential strength EN 206:2013+A2:2021, 5.5.1.1 and 5.5.1.2 shall apply. Additional provisions are given in 5.1.1.

4.2.2.2.3 Direct structural strength

Compressive direct structural strength shall be determined from the finished product by drilling cores in accordance with EN 12504-1 or by cut prisms converted to cube or cylinder with the appropriate correction factor. Non-destructive tests on the finished product in accordance with EN 12504-2 may be used, but a correlation with tests as specified in 5.1.1 shall be established.

4.2.2.2.4 Indirect structural strength

For stabilized production processes where the composition of the concrete and curing methods are not changed, compressive indirect structural strength may be determined by test specimens, made from fresh concrete, cured and stored in factory conditions as close to the precast concrete product as possible, provided an initial test has determined the correlation with the direct structural strength.

Density may be used as a characteristic for the establishment of the correlation.

For transient situations during production, maturity functions may be used to determine the structural strength if a correlation between strength and maturity age has been established during the initial testing.

4.2.2.2.5 Conversion factor

The relation between the structural strength and the potential strength is established by dividing the structural strength by $\eta = 0,85$.

NOTE The value of 0,85 is the recommended value of conversion factor η given in EN 1992-1-1:2004, A.2.3.

4.2.2.3 Tensile strength

If required, tensile strength should be determined according to EN 1992-1-1:2004, 3.1.2 in one of the following ways:

- by axial tensile strength test;
- by flexural strength test according to EN 12390-5 at the same age;
- from the compressive strength according to EN 12390-3 at the same age;
- from the splitting tensile strength according to EN 12390-6 at the same age.

4.2.2.4 Shrinkage

For lightweight concrete, the drying shrinkage shall be determined by the manufacturer, according to EN 1992-1-1:2004, 11.3.3.

4.2.2.5 Dry density

If required, dry density shall be determined in accordance with EN 12390-7 under “oven-dried conditions”.

4.2.2.6 Water absorption

If required for durability reasons or by provisions applicable in the place of use of the concrete product, water absorption shall be determined following Annex F.

4.2.3 Structural reinforcement

4.2.3.1 Processing of reinforcing steel

Reinforcing steel for structural purposes that is straightened, bent or welded in the factory shall remain in compliance with 4.1.3 after this treatment.

Welded connection of reinforcing bars may only be used when the weldability of the steel is established and documented.

Indications on welding process can be found in EN 1992-1-1:2004, 3.2.5.

4.2.3.2 Tensioning and prestressing

4.2.3.2.1 General

The following provisions apply only to prestressing by pre-tensioning. For post-tensioning during manufacturing or on site, EN 13670 applies.

4.2.3.2.2 Initial tensioning stresses

The maximum prestressing force applied to a unit immediately after release of tendons shall satisfy the following conditions:

- absence of uncontrolled longitudinal cracking, spalling or bursting of the concrete;
- the stress in the concrete does not lead to excessive creep or deformation of the product.

When compliance of the product with the relevant specifications of the product standard is demonstrated by initial type testing and factory production control and the tightened tolerances of 4.2.3.2.3 are met, the maximum value of tensioning stress $\sigma_{p_{\max}}$ can be taken as in Formula (1):

$$\sigma_{p_{\max}} = \min(0,85 f_{pk} \text{ or } 0,95 f_{p0,1k}) \text{ class 1} \quad (1)$$

If the conditions mentioned in the previous paragraph are not met, EN 1992-1-1:2004, 5.10.2.1, shall apply as according to Formula (2):

$$\sigma_{p_{\max}} = \min(0,80 f_{pk} \text{ or } 0,90 f_{p0,1k}) \text{ class 2} \quad (2)$$

NOTE The values of 0,8 and 0,9 are the recommended values in EN 1992-1-1:2004, 5.10.2.1.

4.2.3.2.3 Accuracy of tensioning

If class 1 according to 4.2.3.2.2 is applied, tightened tolerances on the prestressing force shall be applied with an accuracy of:

- single tendon/force: $\pm 5 \%$.

If class 2 according to 4.2.3.2.2 is applied, normal tolerances on the prestressing force shall be applied with an accuracy of:

- single tendon/force: $\pm 10 \%$;
- total force: $\pm 5 \%$.

4.2.3.2.4 Minimum concrete strength at transfer

At transfer of the prestressing force, the concrete shall have a minimum strength $f_{cm,p}$ of 1,5 times the maximum compressive stress in the concrete and not less than 20 MPa (cylinder strength).

The specifications according to EN 1992-1-1:2004, 5.10.2.2 (5) shall be considered.

In any case the strength shall be adequate for the anchorage of the strands.

4.2.3.2.5 Slippage of tendons

Slippage, which is the shortening of the tendon at each end of the element after transfer of the prestress force, shall be limited to the following values:

- for individual tendons (strands or wires): $1,3 \Delta L_0$;
- for the mean value of all tendons on one end of an element: ΔL_0 .

For strands the average value of three circumferentially positioned wires shall be taken into account.

The value of ΔL_0 , in millimetres, shall be calculated according to Formula (3):

$$\Delta L_0 = 0,4 l_{pt2} \frac{\sigma_{pm0}}{E_p} \quad (3)$$

where

l_{pt2} is the upper bound value of transmission length = $1,2 l_{pt}$ in mm according to EN 1992-1-1:2004, 8.10.2.2;

σ_{pm0} is the initial stress in the prestressing steel immediately after release, in MPa;

E_p is the modulus of elasticity of the prestressing steel, in MPa.

In general, slippage of tendons is measured except for products prestressed one by one in individual moulds (see Table D.3). On sawn products, visual inspection alone may indicate no slippage and no further measurement is required.

4.3 Finished product specifications

4.3.1 Geometrical properties

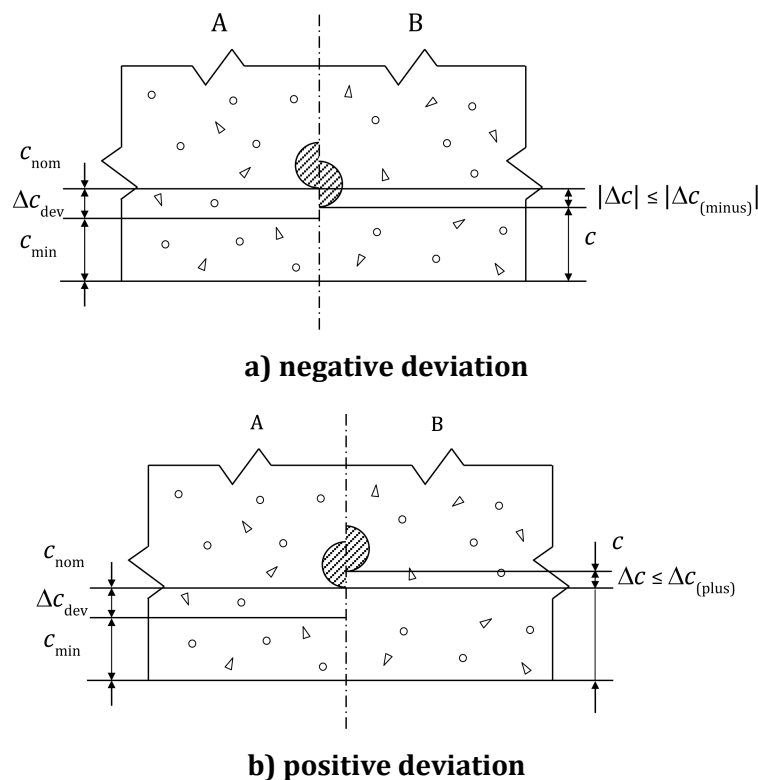
4.3.1.1 Production tolerances

Recommendations for maximum deviations of cross-sectional dimensions [width (Δb) and height (Δh)], and for maximum deviation of concrete cover ($\Delta c_{(plus)}/\Delta c_{(minus)}$) to bars, wires and strands are given in Table 4.

Table 4 — Deviations of cross-sectional dimensions

Dimensions in mm

Target dimension of the cross-section	Deviation $\Delta b, \Delta h$ ^a	Concrete cover ^{a b} $\Delta c_{(plus)}/\Delta c_{(minus)}$
$b \text{ or } h \leq 150$	+10/-5	+5/-5
$b \text{ or } h = 400$	+15/-10	+15/-10
$b \text{ or } h \geq 2\,500$	±30	+25/-10
^a Linear interpolation for intermediate values. ^b With $ \Delta c_{(minus)} \leq \Delta c_{dev} $; according to EN 1992-1-1:2004, 4.4.1.1 and as shown in Figure 1: $c_{nom} = c_{min} + \Delta c_{dev}$. The allowance in design for deviation Δc_{dev} is a Nationally Determined Parameter; hence other values may be valid in the place of use. Where permitted, a manufacturer may declare smaller values for Δc_{dev} than given in the National Annex by taking the appropriate measures.		



Key	
A	drawing
B	actual product
c	actual cover
c _{nom}	nominal cover
c _{min}	required minimum cover
Δc _{dev}	allowance in design for deviation
Δc	actual deviation of concrete cover
Δc _(minus)	maximum deviation for negative values
Δc _(plus)	maximum deviation for positive values

Figure 1 — Concrete cover

The structural design of the works shall take into account the tolerances on the supports as specified in the structural design for the works.

EN 1992-1-1:2004, 10.9.5.2 may be used as guidance to determine the assumed ineffective distances from the edge of the support and from the end of the precast concrete product.

For slabs and beams, the average deviation of concrete cover may be determined as the mean deviation of the individual bars, wires or strands in a beam cross-section or over a maximum width of 1 m in a slab. No single bar, wire or strand shall exceed the recommended negative deviation.

NOTE Guidance on concrete cover can be found in Annex A.

Production tolerances of geometrical properties may be determined by measurements according to G.1 to G.3 of Annex G.