

Regulation for the production and execution of concrete, reinforced concrete, and prestressed concrete works

Reference number NE 013-2026

Second draft

Beneficiary:
Ministry of Development, Public Works and
Administration

- November 2025 -

Second draft

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Introduction

(1) This Regulation represents the technical regulation in Romania for the execution of precast products and elements made of concrete, reinforced concrete and prestressed concrete for buildings and engineering structures.

(2) Precast concrete products and elements shall be executed in accordance with the provisions of this Regulation resulting from the revision and completion of NE 013-2002 'Code of practice for the execution of precast concrete, reinforced concrete and prestressed concrete elements', based mainly on Standard SR EN 13369-2023 'Common rules for precast concrete products'.

(3) The provisions of this Regulation are based on the following premises in accordance with legal regulations:

a) the existence of a standard for the precast product and for the design of the precast element developed and checked;

b) precast products and elements are executed:

(i) by staff holding the necessary qualifications and, where applicable, authorised or certified;

(ii) using products that comply with the provisions of the design, applicable technical regulations and legislative provisions;

(iii) according to the product standard or the design, to the performance requirements and criteria provided for in this Regulation and, as the case may be, other applicable technical regulations;

c) the vehicles, machinery and equipment used comply with the applicable legal provisions;

d) knowledge and implementation of the legal provisions on hygiene and occupational safety, as well as those on fire prevention and firefighting, when executing products and elements.

(4) This Regulation shall apply subject to compliance with the specific rules in the regulations and standards in force relating to: the design of concrete, reinforced concrete and prestressed concrete elements and structures; concrete component materials and testing methods; concrete production and testing methods for fresh and hardened concrete; the execution of concrete structures and assessment of the strength of concrete in structures (Figure 1).

(5) Where additions/adaptations have been made to parts of Standard SR EN 13369-2023 in the content of the Regulation or its Annex to make it easier to follow and understand the paragraphs, the text has been cited in full, respecting the numberings in the standard. All annexes to the standard that were not reproduced in the Regulation, namely Annexes D, F (regulatory), A, B, C, E, G, H, I, J, K, L, M (informative), were considered and referenced; Annexes A, B, C, D, E, F (regulatory) G, H (informative) have been added to this Regulation, which have different content from those in the standard, with the same notation.

(6) In particular, the following points were subject to revision and addition in the Regulation:

a) updating and addition of reference documents, terms, definitions, symbols and abbreviations;

b) concrete component materials and their fields of use according to the type of concrete, simple, reinforced or prestressed, and the respective exposure classes;

c) performance requirements and criteria, testing and conformity assessment methods that have been treated independently but in a uniform manner for concrete component materials, concrete and finished product, precast element;

d) introduction of the modern principles of design and assurance of the durability of concrete regarding the concept of equivalent performance of concrete and the introduction of environmental resistance classes;

- e) a more detailed presentation of the behaviour and construction of prestressed concrete elements, including in terms of prestress losses;
- f) concrete treatment procedures, including thermal treatment;
- g) assessment of the compressive strength of concrete from precast elements by applying the maturity method;
- h) the procedures for applying indirect methods for assessing the compressive strength of the concrete in precast elements;
- i) detailing the manner of drawing up technical documentation and performing inspections.

(7) For the application of this Regulation, the Romanian, European and international standards to which reference is made are used (i.e. Romanian standards that are identical to them).

(8) This Regulation will be applied under climatic and geographical conditions specific to Romania and with levels of protection established according to current national and international experience. The limit values imposed for concrete composition and properties have been introduced into this Regulation to cover these situations.

(9) This Regulation contains guidelines for the use of component materials that are covered by standards, European technical assessments or technical approvals in constructions issued in Romania.

(10) If the concrete complies with the specified values, it is considered that in the precast elements and products also meet the durability requirements for the intended use under the specified environmental conditions to the extent that:

- a) the exposure classes have been correctly selected;
- b) the thickness of the concrete coating is at least equal to that provided in calculation standards for the specific environmental conditions, as set out in SR EN 1992-1-1:2024;
- c) the concrete was manufactured in accordance with NE 012/1;
- d) the concrete has been properly put into operation, compacted and treated/protected in accordance with this Regulation and, where applicable, with NE 012/2;
- e) proper maintenance is carried out throughout the lifetime of the construction.
- f) a routine or special tracking programme is created and implemented, according to each case, based on a technical document prepared by the designer in accordance with P 130/2025.

(11) Performance-based concepts are presented as basic, with the prescriptive concept of limit values representing an accepted alternative, based on the provisions of NE 012/1.

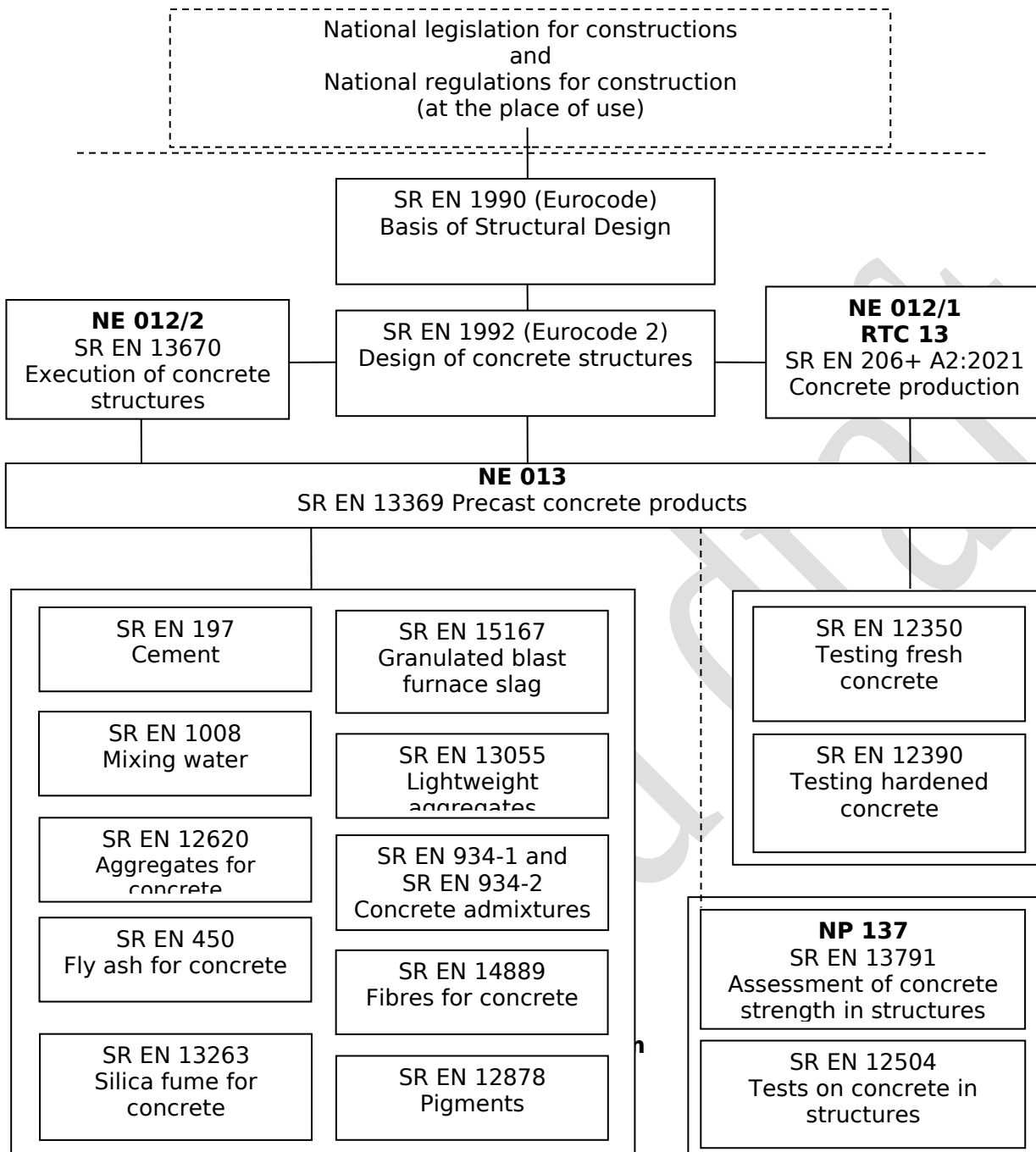


Figure 1. Relationships between the Standard SR EN 13369, the Regulation NE 013 and the design and execution standards, component material standards, test standards and national regulations and guidelines

1. Scope

- (1) This Regulation applies to the manufacture of precast products and the execution of precast elements made of simple concrete, reinforced concrete and prestressed concrete for buildings and civil engineering constructions.
- (2) This Regulation applies to the following types of concrete:
 - a) produced in a prefabricated products factory;
 - b) produced in dedicated manufacturing zones within construction sites, if the manufacturing process is protected against severe weather conditions and monitored in accordance with the provisions of this Regulation;

- c) produced in a concrete plant and delivered to a prefabricated products factory;
- d) heavy, light or normal density;
- e) concrete consisting of natural aggregates, recovered by washing / crushing and recycled;
- f) dispersed reinforced concrete with metallic and polymeric fibers;
- g) compacted or self-compacting, so that the amount of entrapped air, other than the air drawn in, is insignificant;

(3) This Regulation specifies the requirements for:

- a) component materials of concrete;
- b) steel for reinforced and prestressed concrete, as well as other types of embedded metal parts;
- c) the specifications of concrete and reinforcements:
 - the composition of concrete;
 - the production of concrete;
 - the properties of concrete, test methods;
 - the properties of reinforcement for reinforced and prestressed concrete, test methods;
 - assessment and evaluation of constant performance of the concrete;
 - the placement of concrete.
- d) the specifications of the precast element:
 - methods for treating concrete products and precast elements;
 - measurement of the geometric characteristics of the precast element, tolerances;
 - specific characteristics of prestressed concrete elements, the values of the initial and short-term prestressing stresses, the concrete strength at transfer, the maximum permissible values of compressive stresses in concrete, prestress losses;
 - characteristics of the precast element, test methods;
 - assessing and checking the consistency of the performance of the element or precast product.
- e) technical documentation;
- f) inspection schemes/procedures.

(4) Other European standards relating to specific products, precast products or processes falling within the scope of these Rules may require or permit derogations from this document.

(5) This Regulation shall not apply to:

- a) reinforced concrete dispersed with glass fibre;
- b) lightweight aggregate concrete with an open structure

(6) This Regulation does not include requirements relating to health and safety for the protection of operators during the execution, handling, transportation and installation of precast concrete products and elements.

2. Reference documents

(1) The minimum applicable reference documents of a legislative nature are set out below:

- Law No 10/1995 on quality in constructions, republished, including subsequent amendments and additions;

- Government Decision No 668/2017 laying down the conditions for the marketing of construction products;
- Government Decision No 750/2017 amending Annex 5 – Regulation on technical approval for new construction products, processes and equipment – to Government Decision No 766/1997 approving certain regulations on quality in constructions.

(2) The documents presented below are indispensable for the application of this Regulation. For dated references, only the quoted edition applies. For undated references, the last edition of the document referred to (including errata and amendments) shall apply, with the exception of harmonised standards, in which case the edition quoted in the Official Journal of the European Union (OJEU) must be applied.

(3) This Regulation contains references to dated or undated references and provisions in other publications. These references are cited in the appropriate place in the text and the publications are listed below.

(4) In the case of a reference to a draft European standard, the national provisions may be applied until it is available in its final form.

(5) The national reference standards are set out below.

No.	Reference No	Title
1.	SR EN 196-1	Cement test methods – Part 1: Determination of strength
2.	SR EN 196-2	Cement test methods. Part 2: Chemical analysis of cement
3.	SR EN 197-1	Cement – Part 1: Composition, specifications and conformity criteria for common cements
4.	SR EN 197-5	Cement. Part 5: Portland-composite cement CEM II/C-M and Composite cement CEM VI
5.	SR EN 197-6	Cement. Part 6: Cement with recycled building materials
6.	SR EN 206+ A2:2021	Concrete. Specification, performance, production and conformity
7.	SR EN 450-1	Fly ash for concrete. Part 1: Definition, specifications and conformity criteria
8.	SR EN 933-1	Tests for geometrical properties of aggregates. Part 1: Determination of granularity. Grain size analysis by sieving
9.	SR EN 934-1	Admixtures for concrete, mortar and grout. Part 1: Common requirements
10.	SR EN 934-2	Admixtures for concrete, mortar and grout. Part 2: Concrete admixtures. Definitions, requirements, conformity, marking and labelling
11.	SR EN 12878	Pigments for the colouring of building materials based on cement and/or lime – Specifications and methods of test.
12.	SR 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
13.	SR EN 1097-6	Tests for mechanical and physical properties of aggregates. Part 6: Determination of particle density and water absorption
14.	SR EN 1262	Surface active agents. Determination of pH value of solutions or dispersions.
15.	SR EN 1367-1	Tests for thermal and weathering properties of aggregates. Part 1: Determination of resistance to freezing and thawing
16.	SR EN 1367-2	Tests for thermal and weathering properties of aggregates. Part 2: Magnesium sulfate test
17.	SR EN 1992-1-1:2004	Eurocode 2: Design of concrete structures Part 1-1: General rules and rules for buildings
18.	SR EN 1992-2:2006	Eurocode 2: Design of concrete structures Part 2: Concrete bridges. Design and detailing rules.
19.	SR EN 1992-1-1:2024	Eurocode 2: Design of concrete structures. Part 1-1: General rules and rules for buildings, bridges and civil engineering structures
20.	SR ISO 7150-1	Water quality. Determination of ammonium. Part 1: Manual spectrometric method

No.	Reference No	Title
21.	SR EN ISO 7980	Water quality. Determination of calcium and magnesium. Atomic absorption spectrometric method
22.	SR EN ISO 12696	Cathodic protection of steel in concrete
23.	SR EN 12350-1	Testing fresh concrete – Part 1: Sampling and common apparatus
24.	SR EN 12350-2	Testing fresh concrete – Part 2: Slump test
25.	SR EN 12350-4	Testing fresh concrete. Part 4: Degree of compactability
26.	SR EN 12350-5	Testing fresh concrete. Part 5: Flow table test
27.	SR EN 12350-8	Testing fresh concrete. Part 8: Self-compacting concrete. Slump flow test
28.	SR EN 12350-9	Testing fresh concrete. Part 9: Self-compacting concrete. V-funnel test
29.	SR EN 12350-10	Testing fresh concrete. Part 10: Self-compacting concrete. L box test
30.	SR EN 12350-11	Testing fresh concrete. Part 11: Self-compacting concrete. Sieve segregation test
31.	SR EN 12350-12	Testing fresh concrete. Part 12: Self-compacting concrete. J-ring test
32.	SR EN 12390-1	Testing hardened concrete. Part 1: Shape, dimensions and other requirements for specimens and moulds
33.	SR EN 12390-2	Testing hardened concrete. Part 2: Making and curing specimens for strength tests
34.	SR EN 12390-3	Testing hardened concrete. Part 3: Compressive strength of test specimens
35.	SR EN 12390-5	Testing hardened concrete. Part 5: Flexural strength of test specimens
36.	SR EN 12390-6	Testing hardened concrete. Part 6: Tensile splitting strength of test specimens
37.	SR EN 12390-7	Testing hardened concrete. Part 7: Density of hardened concrete
38.	SR EN 14651	Test method for metallic fibre concrete. Measuring the flexural tensile strength (limit of proportionality (LOP), residual)
39.	SR EN 10080	Steel for the reinforcement of concrete. Weldable reinforcing steel. General information
40.	SR EN ISO 17660-1	Welding. Welding of reinforcing steel. Part 1: Load-bearing welded joints
41.	SR 438-1	Steel products for concrete reinforcement. Part 1: Hot rolled structural steel. Quality marks and technical conditions
42.	prEN 10138-1	Prestressing steels - Part 1: Wire
43.	prEN 10138-2	Prestressing steels - Part 2: Strand
44.	prEN 10138-3	Prestressing steels - Part 3: Bar
45.	SR CEN/TR 15739	Precast concrete products. Concrete finishes. Identification elements
46.	SR EN 12504-1	Testing concrete in structures. Part 1: Cored specimens. Taking, examining and testing in compression
47.	SR EN 12504-2	Testing concrete in structures. Part 2: Non-destructive testing. Determination of rebound number
48.	SR EN 12504-4	Testing concrete in structures. Part 4: Non-destructive testing. Determination of ultrasonic pulse velocity
49.	SR EN 12620	Aggregates for concrete
50.	SR EN 13055	Lightweight aggregates.
51.	SR EN 13263-1	Silica fume for concrete – Part 1: Definition, specifications and conformity criteria
52.	SR EN 13369:2023	Common rules for precast concrete products
53.	SR 13536	Assessment of water, soil and gases for their aggressiveness to concrete. Collection and examination of water and soil samples.
54.	SR EN 13577	Chemical attack on concrete. Determination of aggressive carbon dioxide content in water
55.	SR EN 13670	Execution of concrete structures.
56.	SR EN 13791	Assessment of in-situ compressive strength in structures and precast concrete components
57.	ASTM C 1074	Standard Practice for Estimating Concrete Strength by the Maturity Method
58.	SR EN 15167-1	Ground granulated blast furnace slag for use in concrete, mortar and

No.	Reference No	Title
		grout. Part 1: Definitions, specifications and conformity criteria
59.	SR ISO 16204	Durability – The design working life of concrete structures
60.	CEN/TR 16563	Principles of the equivalent durability procedure

(6) The latest editions of the Romanian reference standards shall be used, where applicable, together with the national annexes, amendments and errata published by the national standardisation body.

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(7) The reference technical regulations are listed below.

Ref . no.	Technical regulation
1.	Regulation for concrete production and execution of concrete, reinforced concrete and prestressed concrete works. Part 1: Production of concrete, reference number NE 012/1-2022, approved by Order No 30/2023 of the Minister of Development, Public Works and Housing, hereinafter referred to in this normative document as NE 012/1.
2.	Regulation for concrete production and execution of concrete, reinforced concrete and prestressed concrete works. Part 2: Execution of concrete works, reference number NE 012/2-2022, approved by Order No 28/2023 of the Minister for Development, Public Works and Administration, hereinafter referred to in this normative document as NE 012/2.
3.	Informative Guide on establishing the composition of concrete according to the performance levels of the concrete, reference number RTC 13-2024 approved by Order No 2748/2024 of the Minister for Development, Public Works and Administration, hereinafter referred to in this document as Guide RTC 13-2024.
4.	Regulation for in situ evaluation of concrete strength in existing constructions, reference number NP 137-2014: by Order No 2395/2014 of the Minister of Regional Development and Public Administration, hereinafter referred to in this document as Norm NP 137.
5.	Technical specification for steel products used as reinforcement: requirements and performance criteria, reference number ST 009-2011, approved by Order No 683/2012 of the Minister of Regional Development and Tourism, hereinafter referred to in this document as Technical Specification ST 009
6.	Seismic design code - Part I - Design provisions for buildings, reference number P 100-1/2025
7.	Technical instructions for protection of reinforced concrete and prestressed concrete elements above ground in aggressive natural and industrial environments, reference number C 170/1987
8.	Regulation for the corrosion protection of the concrete elements of the bridge superstructures exposed to climatic factors, noxious substances and the action of chemical fluxes used during the winter, reference number CD 139/2022
9.	Regulation on monitoring the operational behaviour of structures, reference number P 130-2025

(8) The reference pre-normative research used in the legislative framework is: Self-compacting concrete, developed by the Institute of Research for Construction Equipment and Technologies under contract No 435/2009, having as beneficiary the Ministry of Regional Development and Tourism.

(9) The reference technical regulations cited in this Regulation shall be consulted together with the list of regulatory documents in force published by the relevant regulatory authorities.

3. Terms, definitions, symbols and abbreviations

3.1 General

3.1.1

precast concrete element

an element executed in cast concrete in a factory or on site, based on a plan, and hardened in a location other than its final position in the structure

3.1.2

precast concrete product

a product executed in concrete, in accordance with a product standard, using an industrial process within a factory production control system and protected from the weather during production

3.1.3

coating, concrete

the distance between the surface of a reinforcement bar or prestressed reinforcement (including clips, stirrups and surface reinforcement, if applicable) and the nearest concrete surface

3.1.4

minimum coverage

the minimum value of the coverage with concrete, provided to ensure (i) the safe transmission of adhesion forces, (ii) protection of the steel against corrosion (durability), (iii) appropriate fire resistance

3.1.5

coverage, nominal

the specified value of the coverage with concrete, defined as a minimum coating plus a tolerance for deviation in the design

3.1.6

concrete family

a concrete composition group, for which a confidence relationship has been established and documented between the relevant properties

3.1.7

carbon steel

weldable non-alloy steel for reinforced concrete

3.1.8

pretensioning assembly

- in prestressing manufacturing technology, the prestressing assembly is an individual prestressing reinforcement element;
- In post-tensioning manufacturing technology, the prestressing assembly is a complete assembly consisting of anchorages, prestressing steel (strand, wire, bar) and a sheath with a protective layer for applications in non-bonded reinforcement systems, or injected sheaths for applications in bonded reinforcement systems

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3.1.9 reinforcement

a set of bars and/or pretensioning assemblies, whether pretensioned (reinforcement for prestressing the concrete) or not (passive reinforcement), embedded in the concrete elements, which, unless otherwise specified, are made of steel bonding to concrete

3.1.10 profiled reinforcement

reinforcement with at least two rows of ribs that are evenly distributed along the entire length

3.1.11 embossed reinforcement

reinforcement with at least two rows of embossing that are evenly distributed along the entire length

3.1.12 passive reinforcement

non-pretensioned reinforcement that, unless otherwise specified, is made of ordinary reinforcement

3.1.13 pretensioning

a process in which the pretensioning assemblies are stressed prior to and during their incorporation into the poured concrete

3.1.14 pretensioned reinforcement (reinforcement for prestressing the concrete)

reinforcement made of strands, wires or bars subjected to a pretensioning process, made of steel for prestressing

3.1.15 concrete

a material formed by mixing cement, sand, gravel, water and additives, which may contain additions and/or fibres, whose properties are developed by hydrating the cement

3.1.16 effective water content

the difference between the total amount of water contained in the fresh concrete and the amount of water absorbed by the aggregates

3.1.17 entrained air

Microscopic air bubbles deliberately incorporated into concrete while mixing the surfactants; the bubbles are practically spherical and their diameter is generally between 10 μm and 300 μm

3.1.18 occluded air

air voids in concrete that are not produced intentionally

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3.1.19

fresh concrete

concrete that is fully mixed and still at a stage in which it can be compacted using the chosen method

3.1.20

passing ability

the ability of fresh concrete to flow through tight areas, including the spaces between the reinforcement bars, without segregation or blockage

3.1.21

segregation resistance

the ability of fresh concrete to maintain a homogeneous composition

3.1.22

slump flow

the average spread diameter of fresh concrete obtained with a standardised cone

3.1.23

water/cement ratio

the mass ratio between the effective water content and the quantity of cement in fresh concrete

3.1.24

hardened concrete

concrete in solid state and which has acquired significant strength

3.1.25

lightweight concrete

concrete whose density, after oven drying, is greater than or equal to 800 kg/m^3 but less than or equal to $2\,000 \text{ kg/m}^3$

3.1.26

heavy concrete

concrete whose density, after oven drying, is greater than $2\,600 \text{ kg/m}^3$

3.1.27

normal density concrete

concrete whose density, after oven drying, is greater than $2\,000 \text{ kg/m}^3$ but less than or equal to $2\,600 \text{ kg/m}^3$

3.1.28

self-compacting concrete

concrete that can flow and compact under its own weight, capable of filling the formwork, around the reinforcement, ducts and sheaths, maintaining its homogeneity

3.1.29

powders (fine particles)

Material with a particle size of less than 0.125 mm .

Note: This includes cement and the granular fraction of aggregate (filler) and sand below 0.125 mm .

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3.1.30

grout

The concrete part that includes the powder, water, additive and air.

3.1.31

steel fibre reinforced concrete (SFRC)

concrete whose matrix incorporates steel fibres to obtain residual strength after cracking

3.1.32

residual strength class of steel fibre reinforced concrete (SC)

classification that defines the response of an SFRC beyond the specific cracking deformation of the concrete. This class defines the strength of SFRC concrete without additional reinforcement bars or additional prestressing

3.1.33

ductility class of reinforced concrete with steel fibres

classification defined as the ratio between the residual bending strengths at $CMOD_1$ and $CMOD_3$

3.1.34

aggregate

natural, artificial, recovered or recycled granular mineral material suitable for use in concrete

3.1.35

Aggregate recovered by crushing

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

3.1.36

recycled aggregate

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

3.1.37

addition

finely divided mineral material used in concrete to improve certain properties or give it special properties

3.1.38

additive

a product added to concrete during the mixing process, in small quantities relative to the mass of cement, to modify the properties of fresh or hardened concrete. During initial testing, carried out in accordance with Annex A to SR EN 206+A2:2021, tests may be performed to check the performance of a specific type of additive in concrete, in accordance with SR EN 934-2. Compatibility checking in the context of a concrete mix is only required when two or more additives are used

3.1.39

cement

a finely ground mineral material that, when mixed with water, forms a grout that sets and hardens through the effect of hydration processes and reactions and which, after hardening, retains its strength even underwater

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3.1.40

polymer fibres

straight or shaped elements made of extruded, oriented and cut material, which are suitable for homogeneous mixing into concrete

3.1.41

Steel fibres

straight or deformed elements manufactured from cold-drawn steel wires, straight or deformed cut sheets, fibres extracted from molten steel, cold-drawn fibres and fibres rolled from steel blocks, which can be homogeneously mixed into concrete

3.1.42

shrinkage during drying

the shrinkage, additional to the basic shrinkage, that occurs in concrete when there is a transfer of moisture to the surrounding environment

3.1.43

slow creep during drying

slow creep, in addition to basic slow creep, which occurs in concrete when there is moisture transfer with the environment; total slow creep is the sum of basic slow creep and slow creep during drying

3.1.44

standard product

a set of performance levels or classes representative of a construction product, corresponding to its characteristics, manufactured according to a specific manufacturing process, using a given combination of raw materials or other elements

3.1.45

concrete specification

definitive sum of documented technical requirements, from the point of view of performance or composition

3.2 Dimensions

3.2.1

main dimensions

Length, width, depth or thickness

3.2.2

nominal dimensions

the dimensions declared in the technical documentation and used during manufacturing

3.3 Tolerances

3.3.1

tolerance

the sum of the absolute values of the permissible upper and lower deviations

3.3.2

deviation

the difference between an actual measured dimension and the corresponding nominal dimension

3.4 Durability

3.4.1

durability

the ability of a precast concrete element or product to meet, with the anticipated maintenance, the design performance requirements throughout its design working life under the influence of expected environmental actions

3.4.2

design working life

the expected period for which a structure or part thereof is to be used for its intended purpose, with anticipated maintenance but without the need for major repairs

3.4.3

exposure resistance classes ERC

classes for defining the resistance of concrete to carbonation-induced corrosion (XRC) or chloride-induced corrosion (XRDS) and deterioration caused by freeze-thaw attack (XRF)

3.4.4

actions due to the surrounding environment

the physical and chemical actions to which concrete is subjected that have an effect on the concrete, the reinforcement or embedded metal parts and which are not considered loads for the purposes of structural design; this category may also include environmental actions that cause electrochemical corrosion of reinforcements or embedded metal parts, or biogenic corrosion of the concrete

3.4.5

environmental conditions in the production unit

hygrothermal conditions in the factory that have an impact on the concrete hardening process

3.5 Mechanical properties

3.5.1

potential strength

compressive strength of concrete obtained from tests on cubic or cylindrical specimens cast and treated under laboratory conditions in accordance with SR EN 12390-2

3.5.2

maturity method

a method that can be applied to estimate concrete strength, based on the assumption that concretes with the same constituent materials and composition achieve equal strengths at equal values of the maturity index/factor

3.5.3

strength-maturity relationship

the empirical relationship between the strength of the concrete and the maturity index/factor, obtained in the laboratory through the calibration of a concrete mix used for the manufacture of concrete, reinforced concrete or prestressed concrete elements.

3.5.4

structural strength

- direct structural strength, compressive strength of the concrete obtained from tests on specimens (cores or cut prisms) taken from the precast concrete product,
- indirect structural strength, compressive strength of concrete obtained from tests on cast specimens kept under the same environmental conditions as the precast product

3.5.5

characteristic strength

strength value below which a maximum of 5 % of the results of all possible strength determinations carried out for the concrete volume in question are expected to lie

3.5.6

compressive strength class (C)

classification comprising the type of concrete (heavy, light and normal density), representing the minimum characteristic strength on cylinders (150 mm diameter, 300 mm height) and the minimum characteristic strength on cubes (with a side of 150 mm)

3.5.7

conformity assessment

systematic examination of the degree to which a product meets the specified requirements

3.5.8

identification test

a test to determine whether specific mixtures or batches belong to a conforming population

3.5.9

initial test

test(s) to verify, prior to the start of production, how a new concrete or a new family of concretes should be formulated to meet all specified requirements in both fresh and hardened state

3.5.10

check

confirmation through examination of objective evidence that specified requirements have been met

3.5.11

ongoing monitoring

the activity of monitoring the behaviour of structures, consisting in observing and recording aspects, phenomena and parameters that may indicate changes in the

structure's ability to meet the applicable fundamental requirements established by design, in accordance with P130/2025.

3.5.12

special monitoring

the activity of monitoring the behaviour of structures, consisting in the systematic measurement, recording, processing and interpretation of the values of the parameters defining the extent to which the structures continue to meet their fundamental requirements established by design, in accordance with P130/2025.

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3.6 Symbols and abbreviations

X0	Exposure class for no risk of corrosion or attack
From XC1 to XC4	Exposure classes for risk of corrosion induced by carbonation
From XD1 to XD3	Exposure classes for the risk of corrosion induced by chlorides other than from seawater
From XS1 to XS3	Exposure classes for risk of corrosion induced by chlorides from seawater
From XF1 to XF4	Exposure classes for the risk of freeze-thaw attack
From XA1 to XA3	Exposure classes for the risk of chemical attack
From S1 to S5	Consistency classes expressed by slumping
From C0 to C4	Consistency classes expressed by the degree of compaction
from F1 to F6	Consistency classes expressed by the diameter of the spread
From SF1 to SF3	Consistency classes expressed by spreading from slumping
VS1, VS2	Apparent viscosity classes for the t_{500} test
VF1, VF2	Apparent viscosity classes for the t_v test (flow through V-funnel)
t_{500}	Flow time, in seconds, to achieve a spread of 500 mm through a slump spread test
t_v	Flow time, in seconds, for the V-funnel test
PL1, PL2	Passing ability classes for the L-box test
PJ1, PJ2	Passing ability classes by J-ring flow test
SR1, SR2	Segregation resistance classes
C.../...	Compressive strength classes for normal density and heavy concretes
LC.../...	Compressive strength classes for lightweight concretes
SC...	Strength and ductility classes for reinforced concrete dispersed with steel fibre
SCC	Self-compacting concrete
SFRC	Steel fibre reinforced concrete
f_{ck}	Characteristic compressive strength of the concrete Note: When this symbol is used in this standard, it applies to both $f_{ck,cyl}$ and $f_{ck,cube}$.
$f_{ck,cyl}$	Characteristic compressive strength of the concrete, determined by tests performed on cylindrical specimens
$f_{ck,cube}$	Characteristic compressive strength of the concrete, determined by tests performed on cubic specimens
f_{cm}	Average compressive strength of the concrete NOTE: When this symbol is used, it applies to both $f_{cm,cyl}$ and $f_{cm,cube}$.
f_{ci}	Result of the individual concrete compressive strength test
Cl, ...	Chloride class
From D1.0 to D2.0	Density class for lightweight concrete
D	Upper sieving size for an aggregate of defined class d/D

NOTE: SR EN 12620 allows a defined percentage of the aggregate mass to be greater than 'D'.

D_{inf}	The lowest value of D for the aggregates of largest size in the concrete, permitted by the concrete specification
D_{sup}	The highest value of D for the aggregates of largest size in the concrete, permitted by the concrete specification
D_{max}	Declared value of D for the aggregates of largest size actually used in the concrete
CEM...	Cement type according to SR EN 197-1, SR EN 197-5 or SR EN 197-6
σ	Estimated standard deviation of a population
S_n	Standard deviation of n consecutive test results
n	Number
$A_{ef/C}$	Maximum water/cement ratio
D_{cim}	Minimum cement dosage (kg/dm ³)
ρ_c	Cement density (kg/dm ³)
ρ_{ag}	Apparent density of aggregates (kg/m ³)
p	Percentage of entrained and occluded air (dm ³ /m ³)
A_g	Quantity of aggregates in dry state (kg)
$\sigma_{p,max}$	Maximum tensile stress applied to the reinforcement
$\sigma_{p,m}(x, 0)$	Maximum stress after transfer of the prestressing to the anchorage
f_{pk}	Characteristic value of the tensile strength of steel for prestressing
$f_{0.1k}$	Characteristic value of the conventional yield strength at 0.1 % of the steel for prestressing
$f_{cm}(t)$	Average value of the compressive strength of concrete at age t NOTE: When this symbol is used, it shall apply to both $f_{cm}(t)_{cyl}$ and $f_{cm}(t)_{cube}$
$f_{cm,p}$	Minimum compressive strength of concrete at transfer of prestressing force
$\Delta\sigma_{p,i}(x)$	Instantaneous prestress losses
$\Delta\sigma_{p,\mu}(x)$	Prestress losses due to friction between the prestressing steel and the sheath or deflection devices
$\Delta\sigma_{pr}$	Losses due to relaxation of the prestressing reinforcement during the period between tensioning of the reinforcement and prestressing of the concrete
η	Coefficient of 0.85, which represents the ratio between structural strength and potential strength
$C_{min,hard}$	Minimum coverage with concrete c to meet the durability requirements
ERC	Exposure resistance classes
XRC	Classes characterising resistance to corrosion induced by carbonation

XRDS	Classes characterising resistance against corrosion induced by chloride ingress
XRF	Classes characterising resistance to freeze-thaw action
$\Delta_{cmin,30}$	Reduction of minimum coverage for structures with a design working life of 30 years
$\Delta_{cmin,exc}$	Reduction of minimum coverage for superior compaction or treatment
$\Delta_{cmin,p}$	Additional minimum coverage for prestressing assemblies
f_p	Actual tensile strength of the steel for prestressing
f_{pd}	Design value of the yield strength of the steel for prestressing
f_{pk}	Characteristic value of the tensile strength of steel for prestressing
F_y	Reinforcement yield strength
f_{yd}	Design value of the reinforcement yield strength
f_{yk}	Characteristic value of the yield strength of the reinforcement or, if the yield phenomenon is not present, the characteristic value of the conventional yield strength at 0.2 %
f_t	Tensile strength of the reinforcement
$E_{c,eff}$	Effective value of the modulus of elasticity of the concrete, which takes into account deformations due to slow creep
E_{cm}	Secant modulus of elasticity of the concrete
$E_{c,28}$	Secant modulus of elasticity of the concrete at 28 days
E_p	Design value of the modulus of elasticity of the steel for prestressing
ϵ_{ud}	Design deformation of the steel for reinforcement and prestressing at maximum load
ϵ_{uk}	Characteristic deformation of the steel for reinforcement and prestressing at maximum load
ϵ_{yd}	Design value of the deformation at the yield point of the reinforcement
$CMOD_1$	= 0.5 mm is the span of the crack (Crack Mouth Opening Displacement - CMOD) for which the characteristic value of the residual bending strength is determined, $f_{R,1k}$ (defined in SR EN 14651).
$CMOD_3$	= 2.5 mm is the span of the crack (Crack Mouth Opening Displacement - CMOD) for which the characteristic value of the residual bending strength is determined, $f_{R,3k}$ (defined in SR EN 14651).
$f_{R,1k}$	Characteristic value of the residual bending strength at $CMOD_1 = 0.5$ mm, representing the residual strength class
$f_{R,3k}$	Characteristic value of the residual bending strength at $CMOD_3 = 2.5$ mm, representing the performance class
M_{NS}	Maturity factor/index, calculated using the NURSE-SAUL maturity function
M_A	Maturity factor/index, calculated using the ARRHENIUS maturity function
Δt	Time interval, in days or hours
$T_{a,n}$	Mean concrete temperature over the time interval Δt , in °C (if

	applying the NURSE-SAUL maturity function)
T_o	Reference temperature, in °C (if applying the NURSE-SAUL maturity function)
t_e	Equivalent age at the reference temperature, in days or hours, considering strength development as an ARRHENIUS-type function of temperature-dependent exponential maturity
Q	Ratio between the activation energy E and the universal gas constant R equal to 8.314 J/mol-K, in Kelvin
$T_{a,a}$	Mean concrete temperature over the time interval Δt , in Kelvin (if applying the ARRHENIUS maturity function)
T_s	Reference temperature, in Kelvin (if applying the ARRHENIUS maturity function);
s_c	Residual standard deviation, which is a measure of the scatter of the strengths obtained on cores around the regression curve
s_e	Standard deviation of all of the strength values, which is a measure of the scatter of the core strengths around the mean value
n	The number of pairs of results used to establish the calibration curve
m	Number of estimated strength values
s	Standard deviation
n_{eff}	Effective number of degrees of freedom associated with the standard deviation s
$f_{c,m(m)is}$	Average in situ compressive strength of the element
$f_{c,is,reg}$	Value obtained by applying an indirect test converted into the equivalent in situ compressive strength of the element using a regression equation
$f_{ck,is}$	Characteristic in situ compressive strength of the element
k_n	Characteristic quantile factor
$f_{c,is,lowest}$	Lowest value of the in situ compressive strength of the element
M	Margin

4. Specifications for the production of precast products and elements

4.1 Component materials

4.1.1 General information

(1) Only materials established as suitable for use in accordance with the specified requirements, which comply with the regulations, standards in force or national or European technical approvals, where applicable, shall be used in concrete produced in accordance with this Regulation.

(2) Where there are no European standards for a material used in concrete, in accordance with this Regulation, or where an existing European standard does not treat such material, its suitability for use may be established by:

- a) a European Technical Assessment covering, in particular, the use of the component material in concrete, in accordance with standard SR EN 206+A2:2021;

- b) a technical approval in construction relating to the use of the component material in concrete, in accordance with this Regulation or relevant European standards;

Note: technical approvals shall be based solely on the results of experimental research carried out in independent authorised/accredited laboratories.

- c) in the case of cements, the provisions of point 4.1.2 of this Regulation shall be taken into account.

(3)The component materials shall not contain harmful substances in quantities that might have a detrimental effect on the durability of the concrete or cause corrosion of reinforcements and shall be suitable for the intended use – concrete preparation.

Note 1: When the suitability for use of a component material has been established, this does not mean that it can be used in all intended applications and for all concrete compositions.

Note 2: the technical approvals in constructions and the European Technical Assessments for component materials or processes establish their general suitability for use in accordance with this Regulation. In order to establish a particular suitability for use, it is necessary to assess the 'procedure'/component material against the sustainability rules in accordance with these Regulation, Eurocode 2 (SR EN 1992-1-1:2024) and their national annexes NE 012/1, RTC-13 and NE 012/2.

4.1.2 Cement

(1) Cements used for the preparation of concrete used in precast elements and/or precast concrete products must meet the requirements of reference standard SR EN 197-1 applicable or the applicable European standards, SR EN 197-5, SR EN 197-6.

(2) Suitability for use in precast elements and products for normal concrete manufactured with cements in accordance with non-harmonised European standards (e.g. SR EN 197-5, SR EN 197-6) can be established after accepting these standards as reference standards and defining the design and use rules in SR EN 1992-1-1:2024 and the national annex, SR EN 13369 and this Regulation, SR EN 13670 and NE 012/1, with the inclusion of experimental results in accordance with Annex J of NE 012/1.

Note: for all cements for which there is no experience of use in concrete in the country, their use shall be based solely on the results of experimental research carried out in independent, authorised/accredited laboratories with experience in the application of durability methods to demonstrate the appropriate behaviour of concrete under various types of physical, mechanical and environmental stresses, in accordance with normative Annex J to NE 012/1.

(3) In prestressed concretes, it is prohibited to use mixtures of two or more types of cement or cements from several producers in the same element.

(4) When multiple additives are used, their compatibility shall be verified by initial tests, in accordance with Annex A to SR EN 206+A2:2021.

4.1.3. Aggregates

(1) Natural aggregates of normal density, heavy aggregates, as well as air-cooled blast furnace slag, shall comply with the provisions of SR EN 12620 and the provisions of SR EN 13055 for lightweight aggregates, respectively;

(2) Aggregates recovered by crushing and aggregates recycled for use in concrete, mixed with natural aggregates, shall not alter the setting and hardening of the concrete or reduce the durability of the concrete element or precast product.

(3) The requirements for the use of crushed aggregates and recycled aggregates in concrete are considered in accordance with point 4.1.2.2 of SR EN 13369, SR EN 206+A2:2021, Annex E for recycled aggregates with a grain size of $d \geq 4$ mm and Annex N to SR EN 1992-1-1:2024, respectively.

4.1.4 Mixing water

(1) The mixing water shall comply with the provisions and requirements of SR EN 1008.

4.1.5 Additives

(1) Additives shall comply with the provisions and requirements of standard SR EN 934-2.

(2) Additives not mentioned in SR EN 934-2 must comply with the general requirements of SR EN 934-1 and the provisions of the technical approvals in force.

Note: SR EN 934-1 presents the corresponding general requirements in Table 1, Article 5 and Article 6.

4.1.6 Additions (including mineral fillers and pigments)

(1) General suitability for use as a type I addition is established for:

- a. fillers, in accordance with SR EN 12620 or SR EN 13055;
- b. pigments, in accordance with SR EN 12878; for reinforced concrete, only pigments in category B are suitable for use.

(2) General suitability for use as a type II addition is established for:

- a. fly ash, in accordance with SR EN 450-1;

- b. Silica fume, in accordance with SR EN 13263-1;
- c. coefficient for granulated ground blast furnace slag according to SR EN 15167-1.

(3) Suitability for use in precast elements, for type II additions, shall be determined on the basis of experimental results in accordance with Annex J of NE 012/1.

Note: their use shall be based solely on the results of experimental research carried out in independent, authorised/accredited laboratories with experience in the application of durability methods to demonstrate the appropriate behaviour of concrete under various types of physical, mechanical and environmental stresses, in accordance with normative Annex J to NE 012/1.

4.1.7 Fibres

- (1) General suitability for use is established for:
 - a. steel fibres, in accordance with SR EN 14889-1;
 - b. polymer fibres, in accordance with SR EN 14889-2.

4.1.8 Reinforcements for reinforced concrete

(1) The characteristics of reinforcements for reinforced concrete (profiled and embossed bars, including bars straightened from coil, cages and welded meshes, lattice beams), including stainless steel, are specified in SR EN 1992-1-1:2024 Article 5.2 and Annex C of the standard and shall be determined in accordance with SR EN 10080;

(2) Where applicable, the provisions of national Regulations SR 438-1, ST 009 and P100-1 or of national or European technical approvals shall also be taken into account.

(3) Reinforcements for the execution of precast reinforced concrete products and elements shall comply with the requirements set out in Annex (normative) A to this Regulation.

(4) The strength and ductility properties of bars straightened from coil shall be checked to ensure sufficient confidence in the properties of the reinforcement after straightening, in accordance with the national regulations in force; additional requirements may be necessary in terms of meeting the performance related to the profile coefficient f_R (including specific tests to determine the concrete to reinforcement bonding) and fatigue resistance, where required.

(5) The use of reinforcements straightened from coil with a diameter greater than 20 mm is not recommended.

4.1.9 Pretensioned reinforcements (reinforcements for prestressing concrete)

(1) The characteristics of pretensioned reinforcement (strands, wires or bars) are specified in SR EN 1992-1-1: 2024 Article 5.3 and Annex C of the standard and shall be determined in accordance with EN 10138-1, EN 10138-2 and EN 10138-3.

(2) The provisions of ST 009 or of any national or European technical approvals in force shall also be taken into account.

(3) Reinforcements for the execution of precast prestressed concrete products and elements shall comply with the requirements set out in Annex A (normative) to this Regulation.

4.1.10 Inserts and connectors

(1) The basic requirements for inserts and connectors are those set out in Article 4.1.5 of SR 13369.

4.2 Concrete production

4.2.1 Basic requirements for the composition of concrete

(1) The basic requirements for the composition of concrete are those provided for in RTC 13, as well as in Article 5.2 of SR EN 206+A2:2021, namely the choice of cement (Article 5.2.2), the use of aggregates (Article 5.2.3), the use of reclaimed water (Article 5.2.4), the use of additions (Article 5.2.5), the use of additives (Article 5.2.6), the use of fibres (Article 5.2.7), the chloride content (Article 5.2.8), taking into account the additional conditions specified in this Regulation.

(2) When concrete is specified by the manufacturer (concrete with specified properties), the basic requirements (SR EN 206+A2:2021, Article 6.2.2) are given in the design documentation, and additional specifications (SR EN 206+A2:2021, Article 6.2.3) are included only when relevant.

(3) The composition of concrete and the constituent materials for concrete with specified properties or with a prescribed composition shall be selected so as to meet the specified requirements for fresh concrete (including consistency or other particular properties in the case of self-compacting concrete) and hardened concrete: density, strength, durability, corrosion protection of reinforcement and embedded steel parts and, in particular cases, especially for prestressed concrete, modulus of deformation, shrinkage, creep, taking into account the production processes and the method by which the concrete elements or precast products are intended to be executed.

(4) The concrete manufacturer shall select the types and classes of component materials from which the suitability for use is determined for the specific environmental conditions.

(5) The composition of the concrete shall be determined in such a way as to ensure a maximum density of the mineral skeleton and to minimize the segregation and separation of water from fresh concrete.

(6) In the case of concrete with specified properties, the limit values shall be specified in terms of minimum or maximum values and in the case of concrete with the prescribed composition, this shall be specified by target values.

Note 1: The required properties of concrete for use in a precast element are only achieved by complying with the technical regulations and procedures for installation of the concrete. In addition to the conditions set out in this Regulation, it is necessary to take into account the requirements for design, transport, installation, compaction, initial and subsequent treatment before developing the concrete specification (see Articles 4.2.1.2, 4.2.1.3 and 4.2.1.4 of SR EN 13369). These requirements are often unrelated. If all these requirements are met, the differences between the quality of the concrete in the precast element and that of the standardised test specimens shall be taken into account by the partial material safety factor defined for the ultimate limit states (see SR EN 1992-1-1: 2024).

Note 2: the concrete in the precast units shall be prepared in concrete stations whose production control is certified according to NE012/1. The quality of the concrete shall be checked by a laboratory authorised by the State Construction Inspectorate.

4.2.1.1 Choosing the cement

(1) The cement shall be chosen from among those whose suitability for use is established, primarily taking into account:

- a) the type of precast element; whether it is made of plain concrete, reinforced concrete or prestressed concrete;
- b) the final use of the concrete;
- c) the treatment conditions (e.g. heat treatment);
- d) environmental aggressions to which the structure is exposed, classification into an exposure class/combination of exposure classes (see Annexes B and D of this Regulation), taking into account the risks of electrochemical corrosion of reinforcements and biogenic corrosion of the concrete, where applicable;
- e) the potential reactivity of aggregates to alkalis in the component materials.

(2) The cement shall be chosen according to the type of precast element in accordance with Table 4.1, based on the provisions of the product standard and the design, taking into account the specifications of Annex D:

Table 4.1. Choosing cement for products and precast elements

Precast products (based on a product standard)		Additional conditions
Plain concrete	Types of cement corresponding to the exposure classes (Tables D2.1 and D2.2)	without additional conditions
Reinforced concrete	Types of cement corresponding to the exposure classes (Tables D2.1 and D2.2)	without additional conditions
Precast elements (based on a design)		
Reinforced concrete	Portland cement CEM I Portland cements with additions, type CEM II/A	without additional conditions
	Cement types corresponding to exposure classes (Tables D2.1 and D2.2) ⁽¹⁾	based on demonstration, where required, of strength and durability performance (in accordance with Annex J of NE012/1)
Prestressed concrete	Portland cement CEM I Portland composite cement type CEM II/A except for CEM II/A-M types	without additional conditions based on demonstration of appropriate behaviour in terms of strength, modulus of deformation and shrinkage deformations and creep

NOTE⁽¹⁾: The use of these types of cement for precast reinforced concrete elements is based on technical approvals developed under the conditions set out in point 4.1.1(2)(b) depending on the type of structural element.

4.2.1.2 Choosing the aggregates

(1) The type and categories of aggregates, in particular granularity, flattening, freeze-thaw resistance, abrasion resistance, fine particle content and chloride content must be selected taking into account:

- a. the type of precast element;
- b. the recommended use of the concrete;
- c. the performance of the concrete, mainly compressive strength;
- d. the environmental conditions to which the concrete will be exposed;
- e. all requirements applicable to apparent aggregates and aggregates for decorative concrete.

(2) D_{max} must be $\geq D_{inf}$ and $\leq D_{sup}$ and $D_{inf} \geq 8$ mm.

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(3) The recommended particle size zones for concrete preparation are presented in Figures C1, C2, C3, C4, C5 of Annex C to this Regulation, for different maximum nominal dimensions of aggregates 0/8, 0/16, 0/22.4 (22), 0/31.5 (32) and 0/63 mm. Recommendations for the preparation of self-compacting concrete are presented in the pre-regulation research 'Self-compacting concrete'.

(4) In cases where crushed aggregates are used, the overall granularity of the aggregate shall be in the area immediately above (higher in fine particles) that normally indicated at the cement dosage in question.

(5) The basic requirements for the use in concrete of aggregates recovered by crushing and recycled aggregates provided for in Article 4.1.2.2 of SR EN 13369, in SR EN 206+A2:2021, in Annex E and Annex N of SR EN 1992-1-1:2024 for recycled aggregates with a grain size of $d \geq 4$ mm shall be taken into account.

(6) If the appearance of the fresh concrete is satisfactory and does not adversely affect the execution of the products or precast elements, deviations from the curves recommended in Annex C to this Regulation may be permitted, provided that the required performance levels of the fresh and hardened concrete characteristics are checked and achieved.

4.2.1.3 Choosing additives

(1) The concretes are prepared with additives. The conditions for the use of additives are determined mainly according to the type of concrete, the technology and the casting conditions, which are presented in Table 4.2.

(2) The total amount of additives used must not exceed the maximum dosage indicated by the additive manufacturer and it is recommended that it should not exceed 50 g of additive per kg of cement unless the influence of a higher dosage on the characteristics of the concrete has been determined and taken into account.

(3) Additives used in an amount of less than 2 g/kg cement must be dispersed in part of the mixing water, except for additives which cannot be dispersed homogeneously (for example because they form a gel). In this case, other methods shall be used to add them to the concrete.

(4) If the total amount of liquid additive (in solution) is greater than 3 l/m³ concrete, its water content shall be taken into account when calculating the water/cement ratio.

(5) When several additives are used, their compatibility shall be checked in the initial tests.

Note: if the compatibility test for the air entraining additive combined with other types of additives has not been performed by the additive supplier, this test must be performed during the initial tests. The check shall be carried out in accordance with SR EN 480-1 by the concrete manufacturer's laboratory or a laboratory designated by the manufacturer.

Table 4.2. Conditions for the use of additives

No.	Concrete type, casting technology and conditions	Recommended additive	Observations
1	Concretes in strength classes C12/15 to C25/30	Water Reducer/Plasticiser	As applicable: - intense water reducer/ Superplasticiser
2	Concretes subject to repeated freeze-thaw processes	Air entrainer and a Water reducer/Plasticiser	As applicable: - intense water reducer/ Superplasticiser
3	Low permeability concretes	Intense water reducer/ Superplasticiser Waterproofing agent ⁽¹⁾	Where applicable (depending on the exposure): - waterproofing
4	Concrete exposed to conditions of intense and very intense aggression	Intense water reducer/ Superplasticiser	
5	Fluid concretes in class \geq C30/37	Intense water reducer/ Superplasticiser	As applicable: - air entrainers; - hardening accelerators; - setting retardants - shrinkage reducers
6	Self-compacting concretes	Intense water reducer/ Superplasticiser	As applicable: - intense water reducing/superplasticiser+ viscosity-modifying additives - air entrainers; - hardening accelerators; - setting retardants.
7	Concretes with high short-term strength	Superplasticisers	As applicable: - hardening accelerators
8	Semi-dry concretes in class \geq C30/37	Water Reducer/Plasticiser	As applicable: - intense water reducer/ Superplasticiser - air entrainers - hardening accelerators

Note 1: the use of these additives shall be documented, specifying:

- a) the humidity exposure conditions of the element/structure;
- b) the additional conditions regarding the composition and production of the concrete, the impact on the properties of the fresh and hardened concrete.

Note 2: If an additive with two or three functions is used (e.g. superplasticiser and accelerator), the product certification and documentation shall include verification of all declared properties. This verification shall be carried out by the concrete manufacturer or a laboratory designated by the latter, based on the technical documentation submitted by the additive manufacturer.

4.2.1.4 Limit values for the composition of the concrete

(1) The requirements for concrete to withstand environmental aggression are often given in terms of limit values, for the composition of the concrete and the established properties of the concrete; alternatively, the requirements may derive from performance-based methods (see 4.2.1.5). The requirements shall take into account the design working life of the element/structure.

(2) In view of the emergence of European standards for direct concrete performance tests and the need to have a uniform approach to the resistance of concrete to environmental aggression by using different concrete component materials in accordance with this Regulation, the requirements for exposure classes can be detailed by performance criteria. Details are presented in Annex J (normative) to NE 012/1.

- (3) The requirements for each exposure class shall be specified in terms of:
- a) types of component materials;
 - b) maximum effective water/cement ratio;
 - c) minimum cement content;
 - d) minimum compressive strength class of the concrete;
- and if applicable:
- e) minimum air content in the concrete;
 - f) requirements regarding technological processes (e.g. sanding or protective coating).
- (4) The nationally applicable provisions for concrete are determined on the basis of ensuring a working life established by design (designed).
- (5) In the case of combinations of exposure classes, the most demanding requirements of each class shall be taken into account.
- (6) In accordance with SR EN 206+A2:2021, it was established that the maximum effective water/cement ratio should be indicated by an increase of 0.05 and the minimum cement content by an increase of 20 kg/m³. As regards compressive strength, it is recommended that this be indicated in classes, in accordance with Annex F to this Regulation, Table F1.1 for heavy concrete and Table F1.2 for lightweight concrete. Annex D to the Regulation presents the compositional conditions and properties of the concrete, the choice of cements - depending on the type of elements made of plain, reinforced and prestressed concrete - and the maximum fine particle content of the concrete.
- (7) For a lower (e.g. 30-year) or higher (e.g. 100-year) working life, it may be necessary to make the specified limit values more or less severe. Interpretations regarding 'End of working life' and how to calibrate/validate the concrete composition limit values that are provided by provisions at the place of use of the concrete are available in ISO 16204. In this case or for specified concrete compositions, or under special conditions for corrosion protection, for example regarding the thickness of the concrete covering the reinforcement (when this thickness is less than the specifications/provisions of SR EN 1992-1-1:2024 on corrosion protection), special studies are performed by the specification developer for a specific construction, or more generally for national technical regulations. Details are given in Annex J to NE 012/1.
- (8) If the concrete complies with the specified limit values, the concrete in the precast element shall be deemed to satisfy the durability requirements in relation to the intended use taking into account specific environmental conditions, provided that:
- a) the concrete is correctly cast, compacted and treated/protected in accordance with the provisions of SR EN 13369, SR EN 13670 and NE 012/2;
 - b) the concrete covering the reinforcement has the minimum thickness required by the design/design regulation for specific environmental conditions, for example SR EN 1992-1-1: 2024;
 - c) the environmental exposure class is correctly selected;
 - d) handling, storage, transport and installation are carried out in accordance with the provisions of the design;
 - e) preventive maintenance is performed correctly;
 - f) monitoring over time is in accordance with the regulatory requirements.

4.2.1.5 Performance-based design methods

(1) The requirements for concrete related ensuring durability according to exposure classes can be established using performance-based design methods for durability, in

terms of performance parameters (e.g. measuring spalling using a freeze-thaw test, establishing resistance classes (ERC) for different types of exposure), or by applying the equivalent performance procedure. Details are presented in Annex J (normative) to NE 012/1 and RTC 13 for a designed working life of 50 years.

Note: The framework for the equivalent sustainability procedure was published as CEN/TR 16563.

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(2) The application of performance-based methods makes possible the use of component materials, in accordance with the procedures and conditions ensuring that the strength and durability requirements set out in the Regulation are met, in order to ensure the same working life regardless of the component materials used in the preparation of the concrete, including additives in the composition of the concrete.

4.2.1.6 Requirements for fresh concrete

(1) In this Regulation, the provisions relating to the classification of fresh concrete in SR EN 206+A2:2021 Article 4.2., presented in Annex E (normative) to this Regulation, shall be applied (the compaction classes of vibrated concrete and the special classes of self-compacting concrete).

(2) In this Regulation, the provisions of SR EN 206+A2:2021 shall be applied for the requirements relating to fresh concrete, Article 5.4.

(3) The minimum values for the volume of entrained air (in accordance with Annex D (normative) to this Regulation, Tables D.1.1 and D.1.2) are set out in Table 4.3 according to the maximum size of the aggregates.

Table 4.3. Minimum values for the volume of entrained air according to the maximum size of the aggregates

Maximum size of the aggregates (mm)	Entrained air (% volume) mean values	Entrained air (% volume) individual values
16	≥ 5.5	≥ 5.0
22	≥ 5.0	≥ 4.5
32	≥ 4.5	≥ 4.0
63	≥ 4.0	≥ 3.5

4.2.1.7 Strength requirements for hardened concrete

4.2.1.7.1 Compressive strength

(1) This Article deals with the compressive strength of concrete prepared in the concrete plant, checked when casting precast products or elements, defined as the potential strength of concrete, the strength of the concrete in the precast element shall be addressed in Article 5.2 of this Regulation.

(2) This strength shall be determined based on tests carried out on 150 mm cubes or 150 mm/300 mm cylinders according to SR EN 12390-1, made and treated in accordance with SR EN 12390-2, from samples taken according to SR EN 12350-1.

(3) In the case of precast products, where strength requirements are imposed on the final product (e.g. paving slabs), the provisions of the product standard shall apply.

(4) Compressive strength is marked by symbols $f_{c,cub}$ when determined on cubic specimens and marked by symbols $f_{c,cyl}$ when determined on cylindrical specimens in accordance with SR EN 12390-3.

Note 1: Other specimens may also be used, the compressive strength may be equivalent to the strength obtained on 150 mm cubes on the basis of appropriate equivalence ratios, without the results being used to determine the concrete class.

Note 2: It is recommended that the test equipment be equipped in such a way that it can automatically record the results obtained by the compression test of the test specimens, with the possibility of issuing documents.

Note 3: Tests may be carried out 28 days before in order to check that potential strength has been achieved within certain time limits without the results being used to determine

the concrete class. The tests may also be carried out after the 28-days deadline, up to 91 days, in accordance with the provisions of the design, which will specify the time limit, the purpose and the manner of interpreting the results of these tests, in order to define the compressive strength class in accordance with SR EN 1992-1-1.

(5) In this Regulation, the provisions relating to the classification of concrete in SR EN 206+A2:2021, Article 4.3.1, presented in Annex F (normative) of this Regulation, shall be applied and the provisions of Articles 5.5.1.1 and 5.5.1.2 of SR EN 206+A2:2021 shall be applied to determine the potential strength of the concrete.

(6) For design purposes, strength classes are given up to C90/105 for normal and heavy concrete and up to LC 80/88 for lightweight concrete (Annex F to this Regulation).

(7) For prestressed precast concrete elements, the minimum concrete strength class will be C30/37 for normal weight concrete, with the interpretation and application of Tables D1.1, D1.2, D2.1, D2.2 of Annex D being made accordingly. In the case of precast reinforced concrete elements, the minimum class for normal weight concrete shall be C20/25.

(8) The minimum strength for each technological phase (formwork removal, transfer, delivery) shall be established in the design and shall comply with the provisions included in SR EN 1992-1-1: 2024.

(9) In cases where the design does not clearly specify the conditions for these phases, the minimum indicative strengths to be taken into account for each technological phase, only with the notification and agreement of the designer, shall be those specified in Table 4.4.

Table 4.4. Minimum strengths for each technological phase

Compressive strengths by phase			
Concrete class	Strength at formwork removal, reinforced concrete elements	Strength on delivery, reinforced concrete elements	Strength at transfer, prestressed concrete elements
C20/25	14.0/16.5	18.5/23.0	
C25/30	17.5/20.0	23.0/28.0	
C30/37	20.0/23.5	28.5/35.0	27.5/33.5
C35/45	22.5/27.5	31.5/40.5	30.0/38.5
C40/50	25.0/30.0	35.0/43.5	34.0/42.0
C45/55	27.5/32.5	38.5/47.0	37.5/45.5
C50/60	30.0/35.0	42.0/51.5	41.5/50.0
C55/67	32.5/38.5	45.5/55.5	45.0/54.5
C60/75	35.0/42.5	50.0/61.0	49.0/61.0
C70/85	40.0/47.5	56.0/68.5	57.0/69.0
C80/95	45.0/52.5	64.0/75.5	65.0/77.0
C90/105	50.0/57.5	71.0/83.0	73.5/85.5
C100/115	55.0/62.5	82.0/90.0	85.5/93.5

4.2.1.7.2 Tensile strength

(1) In this Regulation, the provisions relating to determination of tensile strength according to SR EN 13369 Article 4.2.2.3 shall be applied.

(2) Where the tensile strength of the concrete has to be determined by splitting it, this must be done at 28 days in accordance with SR EN 12390-6.

Note 1: The characteristic splitting tensile strength determined by must be greater than or equal to the characteristic splitting tensile strength specified in accordance with Article 8.2.2.3 of SR EN 206+A2:2021.

Note 2: The same approach can be used when determining bending strength in accordance with test standard SR EN 12390-5.

(3) The bending tensile strength of reinforced concrete dispersed with metallic fibres shall be determined in accordance with SR EN 14651 for the classification of concrete into concrete classes given in Annex F (normative) of this Regulation.

4.2.1.8 Designing the composition of the concrete

(1) In order to determine the composition of the concrete, the following steps shall be followed:

a) determination of the indicative quantities of effective water (A_{ef}) is evaluated by applying the equation:

$$A_{ef} = D_{cim} \frac{A_{ef}}{C} = A' + Ad - A_{WA24} = A_t - A_{WA24}$$

Where:

A_{ef} the indicative quantity of effective water, which depends mainly on the strength class of the concrete, the compaction, the type and maximum size of the aggregates, the type of cement and the type of additive used (litres);

A' the quantity of mixing/preparation water (litres);

Ad the total quantity of additive, if it exceeds 3 litres;

D_{cim} the minimum cement dosage required for a concrete class falling within a certain exposure class (Tables D.1.1 and D.1.2, Annex D (normative) to this Regulation), (kg/m^3) or the dosage established on the basis of the precast manufacturer's experience, greater than or equal to the minimum;

A_{ef}/C the maximum effective water/cement ratio required for a concrete class within a given exposure class (Tables F D.1.1 and D.1.2, Annex D (normative) to this Regulation);

A_{WA24} the water absorbed by the aggregates;

A_t the total water quantity (including the quantity of additive(s) if this is greater than 3 litres)

b) The quantity of aggregates in dry state A_g (kg) is determined by applying the equation:

$$A_g = \rho_{ag}(1\ 000 - D_{cim} / \rho_c - A_{ef} - P) \quad (1)$$

Where:

ρ_c the density (actual mass per unit volume) of the cement (between 2.9 and 3.1 kg/dm^3 , depending on the type of cement)

Note: The density of the cement used in the concrete mix must be requested from the manufacturer.

ρ_{ag} the actual volumetric mass of aggregates (kg/dm^3) determined in accordance with SR EN 1097-6.

P percentage of occluded air (dm^3/m^3) equal to 2 % (respectively $20 \text{ dm}^3/\text{m}^3$). If air entraining additives are used, P shall be considered indicatively equal to 4 % (i.e. $40 \text{ dm}^3/\text{m}^3$) or corresponding to the determined quantity of entrained air.

c) The quantities of aggregates by size fractions are determined based on the particle size curves in accordance with Annex C (normative) of this Regulation, depending on the maximum size of the aggregates.

(2) The essential characteristics of the concrete shall be provided in the design in abbreviated form, in the following format:

- a) reference to Standard NE012/1 and European Standard SR EN 206+A2:2021;
- b) compressive strength class: the strength class as defined in Tables F1.1 and F1.2, e.g. C25/30, Annex F (normative) to this Regulation;
- c) exposure class(es): class symbolised in accordance with Annex B (normative) to this Regulation. If the precast element or product is exported, the exposure class will be followed by the abbreviation of the name of the country that formulated the provisions for limit values, concrete composition and characteristics or sets of conditions, e.g. XD2 (RO) when the provisions set out by Romania apply;
- d) maximum chloride content: the class defined in SR EN 206+A2:2021 Table 15, e.g. Cl 0.20;
- e) maximum nominal size of the aggregate, value D_{max} ; for example $D_{\text{max}} 22$;
- f) density, in the case of lightweight concrete: specification of the class symbolised in SR EN 206+A2:2021, Table 14 or the specified value, e.g. D 1.8;
- g) consistency: by classes as defined in Annex E (normative) to this Regulation or the target value.

(3) Details regarding practical application for mix design are presented in Guide RTC 13, Chapter 7.

(4) When designing self-compacting concrete, the provisions of the pre-normative research 'Self-compacting concrete' and other relevant documents shall be taken into account so that all requirements are met for fresh and hardened concrete. The basic requirements for designing the composition are indicated in Table 4.5:

Table 4.5 Basic requirements for self-compacting concrete

Constituent	Typical range by mass (kg/m^3)	Typical range by volume (l/m^3)
Fine grout (powder)	380-600	-
Grout	-	300-380
Water	150-210	150-210
Coarse aggregate	750-1000	270-360
Fine aggregate (sand)	48-55 % of the total weight of aggregate	48-55 % of the total volume of aggregate
Water/powder ratio by volume.	-	0.85-1.10

(5) In the case of fibre-reinforced concrete, due to the fact that the addition of fibres has a negative effect on workability, additional measures are necessary to ensure proper placement. These depend, inter alia, on the choice of appropriate particle size distribution and the amount of superplasticiser additive. Mixture adjustments are mainly necessary in the following cases:

- when fibres are used in concrete with a low compressive strength class, the demand for grout is usually increased;
- the additional surface area of the fibres may require a higher mortar content to reduce the risk of concrete that is difficult to finish;
- the surface coverage of the fibres can influence the properties of fresh concrete, mainly the air content, and it is necessary to evaluate the mixture at this stage.

(6) To ensure the proper consistency of fibre-reinforced concrete, the following are generally recommended:

- a. using a higher fine aggregate content than for an equivalent fibre-free mixture;
- b. reducing the content of coarse aggregates;
- c. using a continuous particle size curve;
- d. increasing the dosage of plasticiser or superplasticiser;
- e. limiting the maximum size of the aggregate to the length of the fibre used.

(7) Where it is necessary to design high-strength concretes (compressive strength class greater than C50/60), the concrete mix may contain:

- a. CEM I or CEM II/A cements with high initial and final strengths, 52.5 R;
- b. mineral aggregates from crushed natural hard rock, preferably from quarries;
- c. fine, very fine or ultrafine mineral additions; in most cases the use of ultrafine silica is essential, especially when very high strength is required, and it is used in accordance with the provisions of SR EN 206+A2:2021, Article 5.2.5.2.3.
- d. superplasticising additives and other types of additives, if applicable.
- e. water.
- f. fibre, where applicable.

4.2.1.9 Additional requirements for hardened concrete

4.2.1.9.1 Modulus of elasticity

(1) Where relevant, the modulus of elasticity shall be determined experimentally, especially in the case of self-compacting concrete or when using a maximum aggregate size < 16 mm in the preparation of concrete;

4.2.1.9.2 Shrinkage and creep of concrete

(1) For light concrete, drying shrinkage shall be determined by the manufacturer in accordance with Article 4.2.2.4 of SR EN 13369, taking into account the provisions of SR EN 1992-1-1:2024, Annex M, for both shrinkage and creep.

(2) For normal weight concrete, the experimental determination of slow shrinkage and creep is required when CEM II/A type cements are used in prestressed concrete elements, in accordance with Annex D (normative) to this Regulation, both for ordinary compacted concrete and when using self-compacting concrete.

(3) In the case of elements subject to thermal treatment, the provisions of SR EN 1992-1-1:2024, Article 13.3.2 shall be taken into account.

4.2.1.9.3 Concrete density

(1) If necessary, the dry density shall be determined in accordance with SR EN 12390-7.

(2) It is recommended to determine the density of the specimens used in the compression test (by weighing); for example, to identify any deviations/non-uniformities.

4.2.1.9.4 Durability of the concrete

(1) The following specifications refer to the concrete used for the manufacture of precast structural elements to ensure a design working life in accordance with SR EN 1992-1-1:2024, NE 012/1 and RTC 13.

(2) The durability of precast concrete elements is ensured if at least the following minimum requirements for concrete are taken into account:

- a. adequate cement content (in accordance with Annex D (normative) to this Regulation);
 - b. the maximum effective water/cement ratio (in accordance with Annex D (normative) to this Regulation);
 - c. maximum chloride content (in accordance with Article 4.2.1.8 (2) of this Regulation);
 - d. minimum concrete strength class (in accordance with Article 4.2.1.7 and Annex D (normative) to this Regulation);
- and, where applicable:
- e. maximum alkali content (in accordance with Article 4.2.1.1 (e) of this Regulation);
 - f. air content (in accordance with Article 4.2.1, Table 4.3 of this Regulation);
 - g. water absorption (in accordance with Article 4.2.1.9.4.1 of this Regulation).

(3) Where applicable, the requirements relating to ensuring the durability of concrete through performance criteria shall be applied in accordance with the provisions set out in Annex J (normative) to NE 012/1 and in Guide RTC 13.

4.2.1.9.4.1 Water absorption on concrete samples

(1) When checking durability requirements, water absorption can be determined in accordance with SR EN 13369, Annex F, on samples cast from the concrete used in the element, samples kept in similar environmental conditions to the precast element, or directly on the precast element or from samples extracted from the precast element in accordance with Article 5.7.3 of this Regulation.

4.3 Reinforcement of the precast reinforced concrete elements

(1) Reinforcement for precast reinforced concrete elements with a structural role, which is rolled, straightened, bent or welded in the factory, must retain its properties in accordance with Article 4.1.8 following these processes.

(2) The welding joints of the reinforcement bars may only be applied once the weldability of the steel has been established and documented.

(3) The welding of reinforcement bars must be designed and detailed, and the welds shall be detailed in the execution specifications.

(4) Where the load is predominantly static, it is recommended that the welding be carried out in accordance with SR EN ISO 17660-1.

(5) Guidance on welding operations is given in SR EN 1992-1-1:2004, Article 3.2.5.

(6) In this Regulation, the provisions on reinforcements and embedded parts, as well as those on reinforcement operations for reinforced concrete elements, shall be applied in accordance with NE 012/2.

4.4 Minimum requirements regarding concrete pouring and compaction

(1) The concrete shall be poured and compacted into formwork/moulds, which shall comply with the relevant provisions of SR EN 13670 and NE 012/2, Chapter 6 and Annex C.

(2) The concrete shall be poured and compacted in such a way that it does not contain a significant amount of (occluded) air, apart from entrained air (e.g. to achieve the required frost resistance), in order to avoid segregation and ensure proper embedding of the reinforcement.

(3) The specific rules presented in NE 012/2, Article 9.4 and Annex F shall be taken into account.

4.5 Treatment of the concrete

(1) Articles 4.2.1.3 and 4.2.1.4 of SR EN 13369 and the provisions of the design/specification shall apply.

4.6 Reinforcement and prestressing of precast elements

(1) The provisions on prestressing in NE 012/2, Chapter 8 and Annex E shall apply to this Regulation, including those relating to prestressing by post-tensioning.

4.6.1 Tensioning the reinforcement and transferring the forces to the concrete

(1) The maximum initial prestressing force applied to the precast element must not cause:

- a. longitudinal cracking, breakage, splitting, local crushing of the concrete;
- b. instantaneous deformations or deformations through excessive creep.

(2) It is recommended that the initial and short-term prestressing stresses, specified by the designer, be limited to the values provided in Table 4.6 or be agreed for a specific design by the relevant parties.

Table 4.6. Limits of the values of the short-term prestressing stresses

Limited stress	Stress limit
Maximum tensile stress applied to the reinforcement ^a , $\sigma_{p,max}$ (Class 2)	$\leq 0.8f_{pk}$
	$\leq 0.9f_{p0.1k}$
Overtensioning ^b (e.g. in the event of development of an unexpectedly high friction force) (Class 1)	$\leq 0.95f_{p0.1k}$
Maximum stress after transfer of the pretensioning to the anchorage ^c , $\sigma_{p,m}(x,0)$	$\leq 0.75f_{pk}$
	$\leq 0.85f_{p0.1k}$
<p>^a The tensioning force may be measured with an accuracy of $\pm 10\%$ for a single reinforcement/force from the final pretensioning force value and $\pm 5\%$ for the total force.</p> <p>^b Overtension is only permitted if the tensioning force can be measured with a $\pm 5\%$ accuracy for a single reinforcement/force from the final pretensioning force value.</p> <p>^c The stress following transfer to the anchorage is determined by subtracting the instantaneous losses (see SR EN 1992-1-1:2024 Article 7.6.3) from the initial stress applied at the active end.</p>	

(3) When the pretensioning force is transferred, the concrete shall have a minimum compressive strength $f_{cm, p}$, established by the designer, which shall be at least 1.50 times greater than the maximum compressive stress in the concrete and not less than 25 MPa (strength determined on a cube).

(4) By design, the compressive stress in the concrete of the structure due to the prestressing force and other loads acting during tensioning or prestress losses shall be limited to $0.40f_{cm}(t_0)$. When the compressive stress at age t_0 exceeds the value $0.40f_{cm}(t_0)$ in the quasi-permanent combination of actions, it is recommended that the non-linearity of slow creep be taken into account. In such cases, the theoretical non-linear slow creep coefficient shall be determined in accordance with Annex B to SR EN 1992-1-1:2024. See also the note to Article 4.7.2.

4.7 Prestress losses

4.7.1 Instantaneous prestress losses

(1) The design shall determine the instantaneous losses $\Delta\sigma_{p,i(x)}$ and it is recommended that the following influences be taken into account for pretensioning and post-tensioning, if applicable:

- a. during the tensioning process: losses due to friction between the prestressing steel and the sheath or deflection devices $\Delta\sigma_{p,\mu(x)}$ in accordance with Article 7.6.3.2 of SR EN 1992-1-1:2024;

- b. during the tensioning process: prestress losses in the anchorage (e.g. slippage in the anchorages) in accordance with Article 7.6.3.3 of SR EN 1992-1-1:2024 and Article 4.2.3.2.5 of SR EN 13369;
- c. when prestressing is transferred to the concrete: losses due to instantaneous deformation of the concrete, see 7.6.3.4 of SR EN 1992-1-1:2024;
- d. losses due to relaxation of the prestressing reinforcement during the period between tensioning of the reinforcement and prestressing of the concrete $\Delta\sigma_{pr}$ (if applicable), see Annex B, Article B.9 to SR EN 1992-1-1:2024. In the case of thermal treatment, the losses due to shrinkage and relaxation are modified and it is recommended that they be assessed accordingly; it is also recommended that the direct thermal effect be taken into account (see 13.4.2 of SR EN 1992-1-1:2024).

(2) The general considerations regarding prestress losses presented in SR EN 13369, Annex H shall also be taken into account.

4.7.2 Time-dependent prestress losses

(1) In the case of precast elements made of prestressed concrete, time-dependent prestress losses must also be taken into account in the design.

(2) It is recommended that time-dependent losses be calculated taking into account the following two cases of stress reduction:

- a) reduction of the specific deformation of concrete due to the phenomena of creep and shrinkage, under the action of quasi-permanent loads; and
- b) reduction of the stress in the steel due to relaxation under tension (see Annex B, Article B.9 of SR EN 1992-1-1:2024).

(3) It is generally permissible to take into account the interaction between relaxation of the prestressing steel and deformation of the concrete due to creep and shrinkage by applying a reduction coefficient of 0.8 to the stress calculated from the relaxation.

Note: the limitations on compressive forces in concrete are applicable to prestressed concrete elements: at $0.6f_{ck}$ (it is permissible for the compressive stress σ_c to be increased to $0.66f_{ck}$ if the coverage is increased by 10 mm or confinement is ensured through transverse reinforcement), under total operating loads (characteristic combination), in XD, XF or XS exposure environments and at $0.45f_{ck}$ under long-term loads (quasi-permanent combination). The first condition aims to avoid longitudinal cracking, while the second condition aims to limit deformations due to creep.

5. Specifications for precast elements

5.1 Geometric properties

5.1.1 Tolerances

(1) In this Regulation, the provisions regarding tolerances according to SR EN 13369, Article 4.3.1.1., shall apply.

(2) The provisions for determining the thickness of the layer of concrete covering the reinforcements are set out in Article 5.7 of this Regulation.

5.1.2 Minimum dimensions and details

(1) In this Regulation, the provisions regarding tolerances according to SR EN 13369, Article 4.3.1.2., shall apply.

(2) The rules regarding the minimum dimensions and composition of the details according to SR EN 1992-1-1:2024 shall apply to the design and be adhered to in the execution.

(3) For details relating to the measurement methods, the provisions shall be applied in accordance with SR EN 13369, Article 5.2.

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5.1.3 Surface characteristics

(1) In this Regulation, the provisions regarding surface characteristics shall apply, in accordance with SR EN 13369, Article 4.3.2.

(2) The design shall take into account the rules for shear transfer along a given interface, such as an interface between two concretes cast at different times, for example between a precast element and a monolithic cast concrete, in accordance with Article 8.2.6 of SR EN 1992-1-1:2024. The reference includes provisions regarding the roughness of interfaces for the manufacturer of precast elements.

(3) To identify surface finishing characteristics, SR CEN/TR 15739 shall apply.

(4) For details relating to the methods for determining the surface characteristics, the provisions of SR EN 13369, Article 5.2 shall apply.

(5) For specific applications, the concrete surface can be treated by covering it with protective films or mechanical grinding in accordance with CD 139, the provisions of the design and this Regulation.

5.2 Mechanical characteristics

5.2.1 Determining the compressive strength of the concrete in the precast element

(1) The compressive strength for checking the concrete strength class is defined in Article 5.2.2 and can be determined on the basis of potential strength (Article 4.2.1.7.1) or structural strength.

(2) The manufacturer may determine the direct structural strength or the indirect structural strength. In the event of a dispute, the direct structural strength shall be used.

5.2.1.1 Direct structural strength

(1) For concrete quality control, the determination of direct structural resistance may be chosen by the manufacturer as an alternative to determination of the potential resistance. The provisions of Annex B to SR EN 13369 shall apply.

(2) The direct structural compressive strength can be determined in accordance with SR EN 12504-1 on cores extracted from the structural element. Non-destructive testing of the precast element in accordance with SR EN 12504-2 is permitted, provided that a correlation is established with the results of destructive testing on concrete samples in accordance with SR EN 13791.

5.2.1.2 Indirect structural strength

(1) For stabilised production processes applied over a long period of time, with sufficient technological experience accumulated, in which the concrete mix and reinforcement methods are not modified, the indirect structural compressive strength may be assessed on samples made of hardened concrete and maintained under factory conditions, as close as possible to the precast concrete product, provided that initial tests establishing the correlation with direct structural strength are carried out, if requested by the designer. The provisions of Annex B to SR EN 13369 shall apply.

(2) The conversion factors for the relationship between indirect structural strength and direct structural strength shall be established in the initial tests. Depending on the shape and/or dimensions of the specimens to be considered, this conversion factor may include a shape and/or dimension conversion factor.

(3) For transient situations during production, one of the maturity functions (NURSE-SAUL or ARRHENIUS) may be used to determine the structural strength of concrete indirectly if during calibration (initial testing) and calibration monitoring (continuous testing) a correlation has been established between its strength, temperature and age using the maturity factor/index (M_{NS} or M_A). Details regarding the application of these functions are presented in Annex G (informative) to this Regulation.

(4) The structural strength of concrete is most often understood to mean compressive strength, but the method can also be used indirectly to determine tensile strength, where this is necessary from a technological or structural point of view.

(5) The relationship between structural strength and the potential strength presented in Article 4.2.1.7.1 is established by dividing the structural strength by $\eta = 0.85$.

(6) When the testing shows that the check of compliance with the methods submitted for determining potential strength and direct structural strength through non-destructive testing (5.2.1.1 (2)) and indirect tests fails to demonstrate compliance, the precast elements produced on the corresponding day shall undergo a direct assessment. This assessment must be carried out by testing the direct structural strength of cores extracted from the precast products. The provisions of Annex B to SR EN 13369 shall apply.

5.2.2 Checking the mechanical strength of precast elements and products

(1) The compressive strength class of the concrete shall be declared;

(2) Determination of the compressive strength of concrete in precast elements to determine the strength class of the concrete shall be carried out according to SR EN 12390-3:

- a. on specimens cast in accordance with SR EN 12390-1 and SR EN 12390-2 (potential strength);
- b. or on core samples in accordance with SR EN 12504-1 (direct structural strength).

(3) In the case of precast products, the strength shall be determined from the specimens or from the finished product, according to the provisions of the product standard.

(4) The maintenance conditions in SR EN 12390-2 do not apply to the determination of direct structural strength.

(5) Different shapes and sizes of test specimens give different values for the strength of the concrete. Thus, appropriate shape factors shall be applied to obtain equivalent cylindrical or cubic strengths in accordance with SR EN 13369 Article 5.1.1 and SR EN 13791. For other shapes and sizes of test specimens, the conversion factors shall be determined by initial testing in accordance with SR EN 206+A2:2021, Article 5.5.1.1.

(6) Mechanical strength may be checked and declared on the basis of the initial type test and during factory production control of the finished product;

(7) In order to demonstrate the durability of the finished product, apart from declaring the compressive strength class, other relevant parameters specified in the project – in the case of precast elements – or in the product standard – in the case of precast products (the provisions of Article 5.7 shall be taken into account), must also be specified.

(8) All relevant structural properties of the element/product shall be taken into account during the design phase, both at the ultimate limit state and at the serviceability limit state.

(9) For prestress losses, the provisions of Article 4.6 shall be taken into account.

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(10) The mechanical strength of the precast element may be checked by applying the following methods:

- a. calculation (in accordance with Article 5.2.2.1);
- b. calculation and testing (in accordance with Article 5.2.2.2);
- c. testing (in accordance with Article 5.2.2.3).

5.2.2.1 Checking by calculation

(1) The design values for mechanical strength obtained by calculation shall be checked in accordance with the specific provisions of SR EN 1992-1-1:2024 and with the additional rules set out therein and in the product standards, as applicable.

5.2.2.2 Checking by calculation and testing

(1) Checking by calculation must be supplemented by testing of the precast elements in the event of application of special structural design/modelling rules not fully covered by the provisions of Article 5.2.2.1, or whenever the designer, contractor or beneficiary deems it necessary.

(2) In such cases, it is necessary to conduct physical testing on a small number of full-scale elements before production begins in order to verify the reliability of the design model used for calculation (initial type tests). The tests shall be carried out, on the basis of a test plan, by applying loads up to the ultimate limit state established in the execution design.

5.2.2.3 Checking by testing

(1) In the case of checking by testing, the declared values shall be checked by direct testing of the strength of the precast elements, applying appropriate statistical criteria.

5.2.2.4 Safety factors

(1) When designing precast elements, the provisions for partial safety factors for materials set out in SR EN 1990, SR EN 1992-1-1:2024 and SR EN 13369, Annex C shall apply.

5.3 Transitional situations

(1) This Regulation shall take into account the transitional situations provided for in SR EN 13369 Article 4.3.3.6, as well as the rules regarding the execution of structures made of precast elements in accordance with NE 012/2. The concrete strengths corresponding to the various transitional situations shall be established in the design and checked experimentally according to the provisions of this Regulation. For transitional stages (e.g. formwork removal, transfer, handling, transport, storage, delivery, assembly), the plan shall include separate provisions (strengths, handling and support plans, etc.). The provisions of Article 4.2.1.7.1(8) and (9), shall also be taken into account.

5.4 Resistance and reaction to fire

(1) In this Regulation, the provisions for resistance and reaction to fire in SR EN 13369, Article 4.3.4, SR EN 206+A2:2021 (Article 5.5.4) and SR EN 1992-1-2:2024 shall apply. Eurocode 2: Design of concrete structures. Part 1-2: Structural fire design.

5.5 Acoustic properties

(1) In this Regulation, the provisions of SR EN 13369 Article 4.3.5 on acoustic properties shall apply.

Second draft

5.6 Thermal properties

(1) In this Regulation the provisions of SR EN 13369 Article 4.3.6 on thermal properties shall apply.

5.7 Durability of the precast element

(1) The following specifications refer to precast elements to ensure a working life in accordance with SR EN 1992-1-1: 2024, in addition to the requirements formulated in Article 4.2.1.9.4 for concrete.

(2) The durability of precast concrete elements is ensured if at least the following minimum requirements are taken into account:

- a. protection of newly poured concrete against drying (in accordance with Article 4.5 of this Regulation);
 - b. minimum strength of the concrete (in accordance with Articles 4.2.1.4 and 4.2.1.7 of this Regulation);
 - c. minimum coverage and concrete quality (in accordance with Article 5.7.2 of this Regulation);
- and, where applicable:
- d. accelerated hydration by heat treatment (in accordance with Article 4.5 of this Regulation)
 - e. specific provisions to ensure the surface integrity of the finished product (in accordance with Article 5.7.1 of this Regulation);
 - f. water absorption (in accordance with Article 5.7.3 of this Regulation).

(3) In the case of products executed in non-structural concrete or when the design working life of the precast elements is shorter or longer than the corresponding value in SR EN 1992-1-1: 2024, the durability specifications can be adapted to the specific field of application.

5.7.1 Surface integrity of the finished product

(1) Where relevant, the surface resistance of the concrete to deterioration processes, such as those caused by certain chemical reactions or physical processes such as freeze-thaw, mechanical abrasion, etc., shall be ensured by appropriate measures based on Standard CD 139 and the requirements of the design/specifications.

(2) In such cases, it is recommended to apply the performance methods and the equivalent durability procedure, in accordance with the provisions for ensuring the surface resistance of concrete in SR EN 13369, Articles 4.3.7.2 and 4.3.7.5.

5.7.2 Minimum coverage of the reinforcement with concrete to ensure protection of the reinforcement

(1) The determination of minimum concrete coverage $c_{\min, \text{hard}}$ which depend on the design working life, exposure class and exposure resistance class (ERC) are presented in Table 5.1 and Table 5.2 respectively and correspond to the provisions of SR EN 1992-1-1: 2024. This is considered the basic method.

Table 5.1. Minimum covering with concrete $c_{min,hard}$ for carbon steel reinforcements – Carbonation

ERC	Exposure class (carbonation)							
	XC1		XC2		XC3		XC4	
	Design working life (years)							
	50	100	50	100	50	100	50	100
XRC 0,5	10	10	10	10	10	10	10	10
XRC 1	10	10	10	10	10	15	10	15
XRC 2	10	15	10	15	15	25	15	25
XRC 3	10	15	15	20	20	30	20	30
XRC 4	10	20	15	25	25	35	25	40
XRC 5	15	25	20	30	25	45	30	45
XRC 6	15	25	25	35	35	55	40	55
XRC 7	15	30	25	40	40	60	45	60

Note 1: The XRC classes for carbonation-induced corrosion resistance are derived on the basis of the carbonation depth [mm] (characteristic value of the 90th percentile) assumed to be obtained after 50 years under reference conditions (400 ppm CO₂ in a constant environment of 65 %-RH and at 20 °C). The value indicated by XRC is expressed as the rate of carbonation [mm/√(years)].

Note 2: The recommended values of the minimum concrete coverage $c_{min,hard}$ imply execution and treatment in accordance with SR EN 13670, both of which should correspond to at least Class 2.

Note 3: The minimum coverage can be increased by an additional safety element $\Delta c_{hard,y}$ taking into account special requirements (e.g. extreme environmental conditions).

Table 5.2. Minimum concrete coverage $c_{min,hard}$ for carbon steel reinforcements – Chlorides

ERC	Exposure class (chlorides)														
	XS1			XS2			XS3			XD1		XD2		XD3	
	Design working life (years)														
	50	100	50	100	50	100	50	100	50	100	50	100	50	100	
XRDS 0,5	20	20	20	30	30	40	20	20	20	30	30	40	30	40	
XRDS 1	20	25	25	35	35	45	20	25	25	35	35	45	35	45	
XRDS 1,5	25	30	30	40	40	50	25	30	30	40	40	50	40	50	
XRDS 2	25	30	35	45	45	55	25	30	35	45	45	55	45	55	
XRDS 3	30	35	40	50	55	65	30	35	40	50	55	65	55	65	
XRDS 4	30	40	50	60	60	80	30	40	50	60	60	80	60	80	
XRDS 5	35	45	60	70	70	—	35	45	60	70	70	—	70	—	
XRDS 6	40	50	65	80	—	—	40	50	65	80	—	—	—	—	
XRDS 8	45	55	75	—	—	—	45	55	75	—	—	—	—	—	
XRDS 10	50	65	80	—	—	—	50	65	80	—	—	—	—	—	

Note 1: The XRDS classes for resistance to chloride-induced corrosion are derived from the chloride penetration depth [mm] (characteristic value of the 90th percentile), corresponding to a reference chloride concentration (0.6 % of the binder mass [cement + Type II additions]), assumed to be achieved after 50 years in concrete exposed to unilateral penetration of reference seawater (30 g/l NaCl) at 20 °C. The value indicated by XRDS is expressed as a diffusion coefficient [$10^{-13}m^2/s$].

Note 2: The recommended values of the minimum concrete coverage $c_{min,hard}$ imply execution and treatment in accordance with SR EN 13670, both of which should correspond to at least Class 2.

Note 3: The minimum coverage can be increased by an additional safety element $\Delta c_{hard,y}$ taking into account special requirements (e.g. extreme environmental conditions).

(2) For temporary structures or those with a design working life of 30 years or less, the reduction in coverage is $-\Delta c_{min,30} \leq 5$ mm compared to the design working life of 50 years, in accordance with Tables 5.1 and 5.2.

(3) It is permissible for the values for $c_{\min, \text{hard}}$ provided in Tables 5.1 and 5.2 to be reduced, $-\Delta_{c_{\min, \text{exc}}} \leq 5$ mm under the following execution conditions:

- a) better concrete compaction can be ensured by the geometric, installation and treatment characteristics (e.g. elements with plate geometry the positions of whose reinforcements are not affected by the execution process);
- b) or the treatment complies with at least treatment Class 3 in SR EN 13670.

(4) In the case of pretensioned or post-tensioned prestressing reinforcements, it is recommended that the coverage values in Tables 5.1 and 5.2 be increased by $\Delta_{c_{\min, p}} = +10$ mm, except in cases where bonded internal post-tensioning systems are provided with a protection level of 2 or 3 and internal non-bonded reinforcements are housed in corrosion-resistant sheaths in accordance with SR EN 1992-1-1:2024.

(5) Alternatively, the corrosion resistance of the steel may be improved by complying with the principles of Article 4.1 of SR EN 1992-1-1:2004. For precast concrete products intended for a normal design working life (50 years), SR EN 13369, Annex A recommends the use of minimum values for concrete coverage of the reinforcement, as per Table A.1, provided that a special factory production quality control defined in NE 012/2, in Article 7.5.(5), is carried out in accordance with Article 6.3 of SR EN 13369. The coverage values in Table A.1 are based on provisions taken directly from SR EN 1992-1-1:2004 and SR EN 206+A2:2021. The values calculated using this method shall not be lower than those determined using the basic method in accordance with 5.7.2(1).

(6) Corrosion resistance can also be improved by protecting the reinforcement or by using stainless steel.

5.7.3 Water absorption on concrete samples extracted from the precast element

(1) When verifying durability requirements, water absorption can be determined in accordance with SR EN 13369, Annex F, on samples cut or cored from precast elements.

5.7.4 Electrochemical corrosion resistance of steel concrete reinforcements

The electrochemical corrosion resistance of concrete steel reinforcements can be obtained by applying SR EN ISO 12696:2022 (Cathodic protection of steel in concrete).

5.7.5 Resistance of the concrete to biogenic corrosion

The resistance of concrete to biogenic corrosion is achieved by the same compositional measures as for weak chemical attack, accompanied by the application of acid-resistant films (where appropriate) and timely maintenance work.

5.8 Other specifications

5.8.1 Safety during handling

(1) In this Regulation, the provisions regarding safety during the handling of precast concrete elements in SR EN 13369, Article 4.3.8.1 and SR EN 13670, Articles 9.4 and 9.5 shall apply.

5.8.2 Safety in use

(1) In this Regulation, the provisions regarding safety during the use of precast concrete elements and products shall apply in accordance with SR EN 13369, Article 4.3.8.2.

5.8.3 Own weight

(1) In this Regulation, the provisions regarding declaration of the dead load of precast concrete elements in SR EN 13369, Article 4.3.8.3 shall apply, applying the methods set out in Article 5.3 of SR EN 13369.

6. Assessment and evaluation of constant performance

6.1 General considerations

(1) In this Regulation, the provisions regarding the assessment and checking of constancy of performance shall apply, in accordance with SR EN 13369, Article 6.

(2) In the case of precast products, the allocation of tasks for the manufacturer and the notified body in the CE marking process is defined in the relevant Annex ZA of the product standard. Certain tasks described in this Regulation may not be relevant to CE marking.

6.1.1 Demonstration of conformity

(1) The conformity of concrete products to the relevant specifications of the product standard and to the performance declared by the manufacturer shall be demonstrated by:

- a. determination of the product type;
- b. factory production control.

(2) The manufacturer shall have the means necessary to carry out the control and shall assume responsibility for conformity of the product to the declared performances.

6.1.2 Evaluation of constant performance

(1) In this Regulation, the provisions regarding the assessment and checking of constancy of performance according to SR EN 13369 Article 6.1.3, which consists in assessment of factory production control and performance assessment, shall apply.

6.1.3 Product groups

(1) In this Regulation, the performance provisions regarding product families shall apply, in accordance with SR EN 13369, Article 6.1.4.

6.2 Performance assessment

(1) In this Regulation, the provisions regarding performance assessment shall apply, in accordance with SR EN 13369, Article 6.2.

6.3 « Factory » production control

(1) In this Regulation, the provisions regarding factory production control shall apply in accordance with SR EN 13369, Article 6.3.

(2) As regards the conformity criteria for assessment of the compressive strength of concrete for the initial phase, before reaching the minimum production period specified in SR EN 13369 Article 6.3.8.1, the assessment shall be based on the criteria given in the formulas:

(2.1) For individual strength:

- a. For concrete classes C12/15 and C16/20, in the case of plain concrete elements, each individual value f_{ci} shall satisfy the following criteria:

$$C12/15: (f_{ci} \geq f_{ck}-2)$$

C16/20: ($f_{ci} \geq f_{ck}-3$)

b. For the other strength classes, the criterion will be:

($f_{ci} \geq f_{ck}-4$)

(2.2) The average strength f_{cm} must satisfy the criterion $f_{cm} \geq f_{ck}+4$ MPa, regardless of the strength class.

where:

f_{ci} is the individual result of the compressive strength of the concrete;

f_{cm} is the average compressive strength of the concrete;

f_{ck} is the characteristic value of the compressive strength of the concrete.

(3) The same criteria shall be applied in the case of non-continuous occasional productions;

(4) The conformity assessment of concrete strength during the continuous production period can be carried out using a control scheme in accordance with the specifications of SR EN 206+ A2: 2021.

(5) Any indirect test method for determining the compressive strength of concrete, e.g. the rebound index method and/or the ultrasonic velocity method, may be used provided that a reliable correlation is established and maintained with the direct destructive method, which is the reference method. In informative Annex H to the Regulation, a method is presented for establishing a correlation between direct and indirect methods.

(6) Annex B to SR EN 13369 gives details of the conformity assessment for the compressive strength of concrete.

(7) In the case of precast elements, structural strength shall only be determined by extraction and testing of cores in special cases (documented in the design, including repair methods) and in cases where elements prove non-compliant in terms of their failure to meet the standards of the potential class or unacceptable surface defects in accordance with Annex G to SR EN 13369.

7. Marking

(1) In this Regulation, the provisions regarding marking shall apply, in accordance with SR EN 13369, Article 7.

8. Technical documentation

(1) In this Regulation, the provisions regarding technical documentation shall apply in accordance with SR EN 13369 Article 8.

ANNEX A

(normative)

Requirements for reinforcements

A1. Reinforcements for reinforced concrete

(1) The specified properties of the reinforcement that are required for design and execution shall include at least:

- a. strength class in accordance with Table A1;
- b. ductility class in accordance with Table A2;
- c. diameter or dimension;
- d. bendability and bending-unbending.

Table A1. Strength classes of reinforcements

Properties shown in the stress-strain diagram (Figure A1)	Strength class of the reinforcement					
	B400	B450	B500	B550	B600	B700
Characteristic value of f_{yk} (MPa)	400	450	500	550	600	700

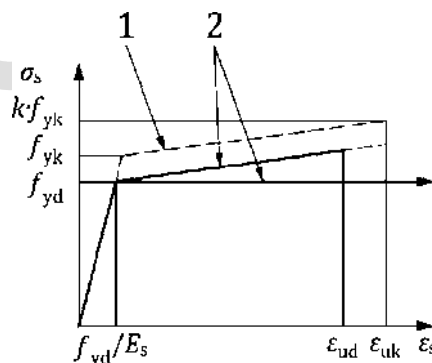
Table A2. Ductility classes of reinforcements

Properties shown in the stress-strain diagram (Figure A1)	Ductility class of the reinforcement		
	A	B	C
Characteristic value of $k = (f_t/f_y)_k$	1.05	1.08	from 1.15 to 1.35
Characteristic value of the strain at maximum force ϵ_{uk}	2.5 %	5.0 %	7.5%

Note 1: SR EN 10080 specifies the tensile yield strength R_e as a characteristic value based on the long-term quality level of production, whereas f_{yk} is the characteristic yield strength based only on the reinforcement used in a given structure. There is no direct relationship between f_{yk} and the characteristic R_e or $R_{p0.2}$. However, on the basis of the assessment and checking methods, the yield strength R_e provided in SR EN 10080 can be considered as f_{yk} .

Note 2: Further specifications relating to the strength and durability characteristics of the reinforcements for reinforced concrete are set out in Annex C to SR EN 1992-1-1:2024.

Note 3: Recommendations regarding embossed bars and wires are given in Annex J to SR EN 13369.



Key

- 1 nominal reference diagram
- 2 design diagrams

Figure A1. Stress-strain diagrams for carbon steel reinforcements (for tension and compression)

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A2. Pretensioned reinforcements (reinforcements for prestressing concrete)

(1) The specified properties of the prestressing steel that are necessary for the design and execution of prestressed concrete elements must include at least:

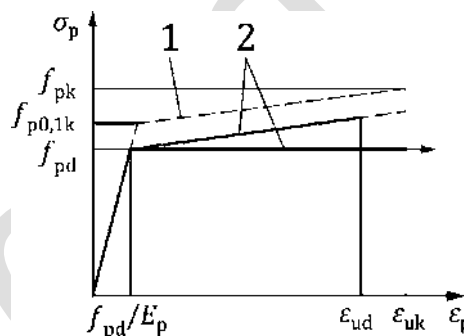
- strength class in accordance with Table A3;
- the product type: wire, strand or bar;
- the diameter or dimension.

Table A3. Strength classes of steel for prestressing

Properties shown in the stress-strain diagram (Figure A.2) (characteristic values)	(a) Wires ^a			
	Y1570	Y1670	Y1770	Y1860
Conventional yield strength $f_{p0.1k}$ (MPa)	1 380	1 470	1 550	1 650
Tensile strength f_{pk} (MPa)	1 570	1 670	1 770	1 860
	(b) Strands ^a			
	Y1770	Y1860	Y1960	Y2060
Conventional yield strength $f_{p0.1k}$ (MPa)	1 560	1 640	1 740	1 830
Tensile strength f_{pk} (MPa)	1 770	1 860	1 960	2 060
	(c) Bars ^a			
	Y1030	Y1050	Y1100	Y1230
Conventional yield strength $f_{p0.1k}$ (MPa)	835	950	900	1 080
Tensile strength f_{pk} (MPa)	1 030	1 050	1 100	1 230

Note^(a): In all strength classes, the value of the stress ratio $k = (f_p/f_{p0.1})_k \geq 1.1$ and the characteristic strain at maximum force $\epsilon_{uk} = 3.5\%$.

Note 1: Further details relating to the characteristics of the prestressing reinforcements are presented in Annex C to SR EN 1992-1-1:2024.



Key

- nominal reference diagram
- design diagrams

Figure A2. Stress-strain diagrams for steel for prestressing (tension only)

ANNEX B

(normative)

Exposure classes

(1) The exposure classes are defined according to the degradation mechanisms envisaged over the design working life of the concrete. The notation used to identify these classes consists of two letters and one digit.

(2) The first letter is X (from eXposure) followed by another one referring to the degradation mechanism considered, as follows:

- C for **C**arbonation
- D for **D**eicing salt
- S for **S**eawater
- F for **F**rost
- A for **A**ggressive environment
- M for **M**echanical abrasion

The second letter is followed by a figure referring to the humidity level (XC, XD, XS, XF) or aggression level (XA, XM).

Note 1: The choice of exposure classes depends on the requirements in force at the place where the concrete is used. This exposure classification does not exclude consideration of the particular environmental conditions existing at the site where the concrete is used or the application of additional protective measures such as the use of stainless steel or other corrosion-resistant metal and/or the use of protective coatings on the concrete or the reinforcement.

Note 2: Whenever appropriate, due attention shall be given to preventing the occurrence of electrochemical corrosion of the steel in the concrete and/or biogenic corrosion of the concrete, with negative consequences on the functionality of reinforced and prestressed concrete elements/structures.

(3) In the case of chemical attack, the aggressiveness of water, soil and gases on concrete will be determined according to SR 13536. Particular studies may be required to determine the appropriate exposure classes if:

- a) they do not fall within the parameters set out in Table B3;
- b) they contain other aggressive substances;
- c) the soil or water is chemically polluted;
- d) they have a high water flow rate in combination with certain chemicals shown in Table B3.

Table B1. Exposure classes

Class name	Description of the surrounding environment	Informative examples illustrating the choice of exposure classes
1. No risk of corrosion or chemical attack		
X0	Plain concrete without embedded metal parts. All exposures, except for the cases of freeze-thaw, abrasion and chemical attack. For reinforced concrete or concrete with embedded metal parts: Very dry	Concrete inside buildings where the moisture content of the ambient air is very low.
2. Corrosion due to carbonation		

Class name	Description of the surrounding environment	Informative examples illustrating the choice of exposure classes
<p>When concrete containing fittings or embedded metal parts is exposed to air and humidity, the exposure shall be classified as follows:</p> <p>Note: the humidity conditions taken into consideration shall be those of the concrete covering the reinforcements or embedded metal parts, but in many cases, this humidity can be considered to reflect the ambient humidity. In this case, a classification based on different ambient environments may be acceptable. The situation cannot be the same if there is a barrier between the concrete and its environment (concrete coated with a protective material).</p>		
XC1	Dry or permanently wet	Concrete inside buildings where the humidity of the environment is low (including kitchens, bathrooms and laundry rooms of residential buildings). Concrete permanently immersed in water.
XC2	Wet, rarely dry	Concrete surfaces in long-term contact with water (e.g. water tank elements). A large number of foundations.
XC3	Moderate humidity	Concrete inside buildings where the ambient humidity is medium or high (kitchens, bathrooms, professional laundry rooms other than those in residential buildings). Concrete that is external but sheltered from the weather (elements to which the outside air has constant or frequent access, for example: open halls).
XC4	Alternating humidity and drying	Surfaces subject to contact with water but not in exposure class XC2 (external elements exposed to the weather).
3. Corrosion due to chlorides of non-marine origin		
<p>When concrete containing fittings or embedded metal parts is in contact with water containing chlorides of non-marine or salt-lake origin, including defrosting salts, the exposure classes are as follows:</p> <p>Note: as regards moisture conditions, see section 2 of this table.</p>		
XD1	Moderate humidity	Concrete surfaces exposed to chlorides carried by air currents (e.g. surfaces exposed to road surface deicing agents sprayed and transported by air currents, garages, etc.).
XD2	Wet, rarely dry	Swimming pools, tanks. Concrete exposed to industrial water containing chlorides.
XD3	Alternating humidity and drying	Bridge elements, retaining walls, exposed to splashing with water containing chlorides. Roads, slabs laid in vehicle parking areas.
4. Corrosion due to chlorides from seawater		
<p>When concrete containing fittings or embedded metal parts is put into contact with chlorides from seawater or exposed to wind action with airborne marine salts, the exposure classes are as follows:</p>		
XS1	Exposure to wind action with airborne marine salts, but not in direct contact with seawater	Structures on or near the coastline (atmospheric marine aggression acts on concrete constructions, reinforced concrete at a distance of 5 km from shore).
XS2	Constantly immersed	Elements of marine structures.
XS3	Tidal zones, zones subject to spray and fog	Elements of marine structures.
5. Freeze-thaw attack with or without deicing agents		
<p>When concrete is subject to significant attack due to freeze-thaw cycles then, when wet, the exposure classes are as follows:</p>		
XF1	Moderate saturation with	Vertical concrete surfaces exposed to rain and

Class name	Description of the surrounding environment	Informative examples illustrating the choice of exposure classes
	water without deicing agents	frost.
XF2	Moderate saturation with water, with deicing agents	Vertical concrete surfaces of road infrastructure exposed to frost and air currents carrying deicing agents.
XF3	Significant saturation with water without deicing agents	Horizontal surfaces of concrete exposed to rain and frost.
XF4	Significant saturation with water, deicing agents or seawater/natural water containing chlorides	Roads and bridge decks exposed to deicing agents. Vertical concrete surfaces exposed to frost and directly sprayed with deicing agents. Areas of marine structures exposed to frost and subjected to splashing with deicing agents

6. Chemical attack

When the concrete is exposed to chemical attack, which occurs through contact with natural soils, surface water and groundwater, classification is made as indicated in Table B3. The classification of seawater depends on the geographical location, therefore the valid classification on the place of use of the concrete shall be applied.

XA1	Environment with low chemical aggression according to Table B3	
XA2	Environment with moderate chemical aggression according to Table B3	
XA3	Environment with intense chemical aggression, according to Table B3	

7. Mechanical loading of concrete due to abrasion

If the concrete is subjected to mechanical loading that causes abrasion then this type of exposure can be classified as follows:

XM1	Moderate abrasion loading	Elements in premises subject to the circulation of vehicles equipped with pneumatic tyres.
XM2	Intense abrasion loading	Elements in industrial premises subject to the circulation of forklifts equipped with pneumatic or solid rubber tyres.
XM3	Very intense abrasion loading	Elements in industrial premises subject to the circulation of forklifts equipped with elastomer/metal solid tyres or vehicles with caterpillar tracks.

Note 1: Concrete may be subject to more than one of the actions described in Table B1, in which case the environmental conditions to which it is subject may be expressed as combinations of exposure classes. In Table B2 there are examples of such combinations. The parts of a particular structural element may be exposed to different environmental actions.

Note 2: When concrete is exposed to chemical attack originating in the atmosphere with aggressive agents in gaseous and solid state, classification shall be made as indicated in Annex I to NE 012/1. In this case, the requirements for component materials and concrete are set out in the document 'Technical instructions for the protection of reinforced concrete and prestressed concrete elements above ground in aggressive natural and industrial environments', reference number C 170.

Table B2. Combinations of exposure classes

Exposure		Combinations of exposure classes	
Description	Examples	BNA ⁽¹⁾	BA ⁽²⁾ / BP ⁽³⁾
Interior	Interior of residential or office buildings	X0	XC1
	Floor slabs of underground car parks		XC4, XD3,

Exposure		Combinations of exposure classes	
	in shopping centres		XM1
Exterior			
No frost	Foundations below the frost level	X0	XC2
Frost but no contact with rain	Covered open garages, passageways, etc.	XF1	XC3 + XF1
Frost and contact with rain	External elements exposed to rain	XF1	XC4+ XF1
Freeze-thaw with deicing agents	Elements of horizontal road infrastructure.	XM2+XF4	XM2+ XD3+ XF4+XC4
	Vertical (in the splash zone)	XF4	XF4+ XD3+ XC4
Marine environment			
No contact with seawater (marine air up to 5 km from the coast)			
With frost	Exterior elements of buildings exposed to rain in coastal areas	XF2	XC4+ XS1+ XF2
In contact with seawater			
Immersed	Structural elements under water	XA1 (XA2)	XC1+ XS2+ XA1 (XA2)
Elements subject to splashing	Quaysides and docks	XF4+ XA2 (XA1)	XC4+ XS3+ XF4+ XA2 (XA1)
¹⁾ Unreinforced concrete ²⁾ Reinforced concrete ³⁾ Prestressed concrete			

(4)The chemically aggressive environments classified below are based on natural soils and groundwater at a water/soil temperature of between 5 °C and 25 °C and in cases where the seepage velocity of the water is low enough for it to be considered static.

(5)The choice of classes is made in relation to the chemical characteristics leading to the most intense aggression.

(6)Where at least two aggressive characteristics lead to the same class, the environment shall be classified in the category immediately above unless a specific study has shown that this is not necessary.

Table B3. Limit values for the corresponding exposure classes to chemical attack of natural soils and groundwater

Chemical characteristics	Reference test methods	XA1	XA2	XA3
Groundwater				
SO ₄ ²⁻ , mg/l	SR EN 196-2	≥ 200 and ≤ 600	> 600 and ≤ 3 000	> 3 000 and ≤ 6 000
pH	SR EN 1262	≤ 6.5 and ≥ 5.5	≤ 5.5 and ≥ 4.5	< 4.5 and ≥ 4.0
CO ₂ aggressive, in mg/l	SR EN 13577	≥ 15 and ≤ 40	> 40 and ≤ 100	> 100 until saturation
NH ₄ ⁺ , mg/l	SR ISO 7150-1	≥ 15 and ≤ 30	> 30 and ≤ 60	> 60 and ≤ 100
Mg ₂ ⁺ , mg/l	SR EN ISO 7980	≥ 300 and ≤ 1 000	> 1 000 and ≤ 3 000	> 3 000 until saturation
Soil				
SO ₄ ²⁻ , mg/l ^a total	SR EN 196-2 ^b	≥ 2 000 and ≤ 3 000 ^c	>3 000 ^c and ≤ 12 000	>12 000 ^c and ≤24 000
Acidity in accordance with Baumann Gully, ml/kg	SR EN 16502	> 200	Not found in practice	

Chemical characteristics	Reference test methods	XA1	XA2	XA3
<p>^a Clay soils whose permeability is less than 10⁻⁵ m/s may be ranked in a lower class.</p> <p>^b The test method provides for extraction of SO₄²⁻ with hydrochloric acid; alternatively, it is possible to perform this extraction with water if this is permitted at the place of use of the concrete.</p> <p>^c The limit of 3 000 mg/kg is reduced to 2 000 mg/kg if there is a risk of accumulation of sulphate ions in concrete due to dry-wet cycles, or by capillary action.</p>				

Note: The limit values for the exposure classes corresponding to the chemical attack of natural earths and groundwater indicated in Table B3 also apply to stationary overground waters in contact with the concrete surface.

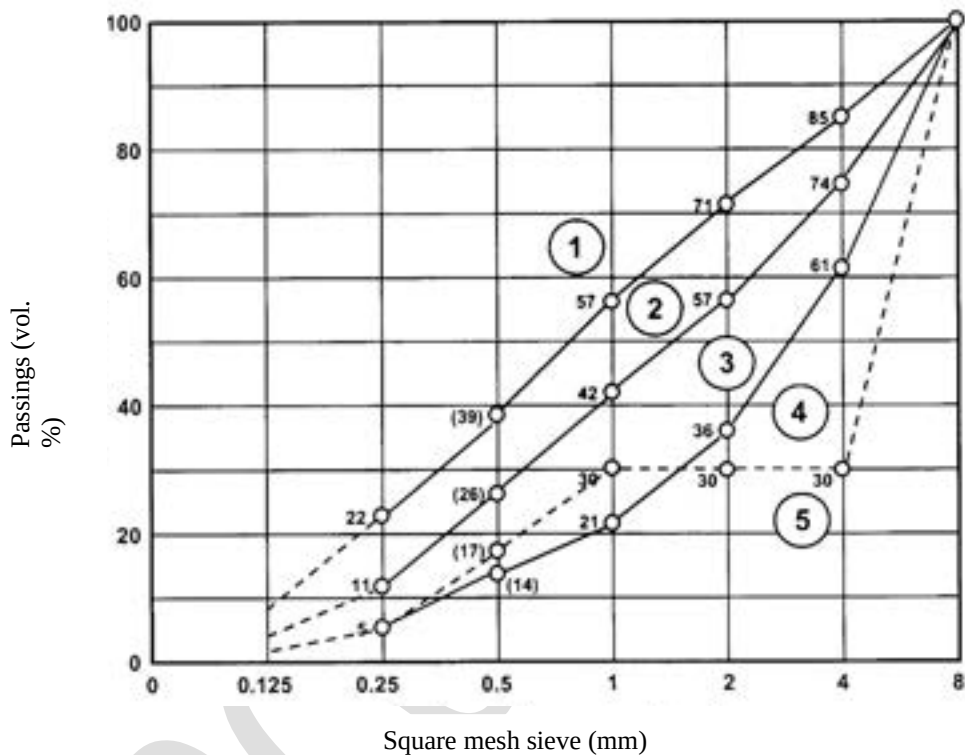
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Annex C

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The granulometric composition of aggregates used in concrete preparation

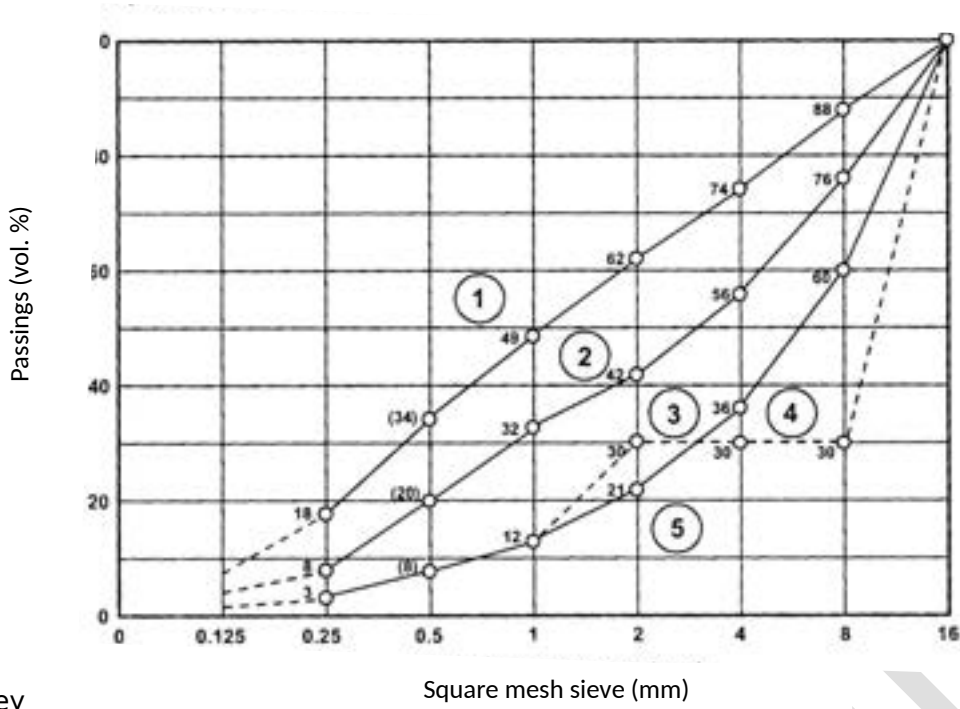
- (1) The granulometric composition of aggregates used in the preparation of concrete is described by the percentage by volume of the aggregate passing through sieves with square mesh dimensions of 0.125 mm, 0.25 mm, 0.5 mm, 1 mm, 2 mm, 4 mm, 8 mm, 16 mm, 22.4 (22) mm, respectively 31.5 (32) mm and 63 mm.
- (2) The granulometric compositions of individual or compound aggregates are determined with regard to SR EN 933-1.
- (3) Figures C1 to C5 show the granulometric zones according to the maximum size of the aggregates.



Key

- ① unfavourable
- ② usable
- ③ favourable
- ④ favourable for discontinuous granulometric composition
- ⑤ unfavourable

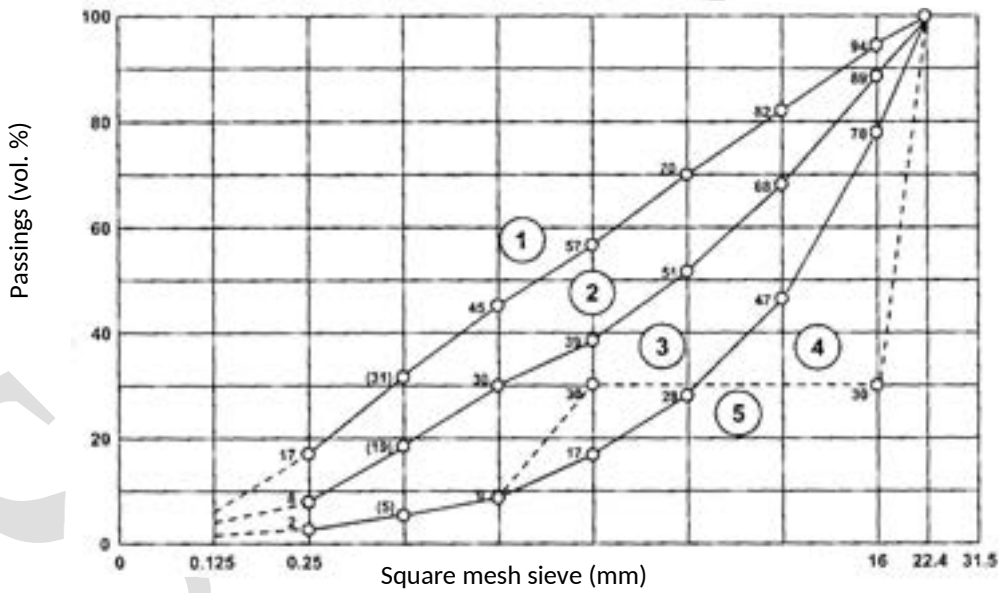
Figure C1. Granulometric zones for the maximum aggregate size of 8 mm



Key

- ① unfavourable
- ② usable
- ③ favourable
- ④ favourable for discontinuous granulometric composition
- ⑤ unfavourable

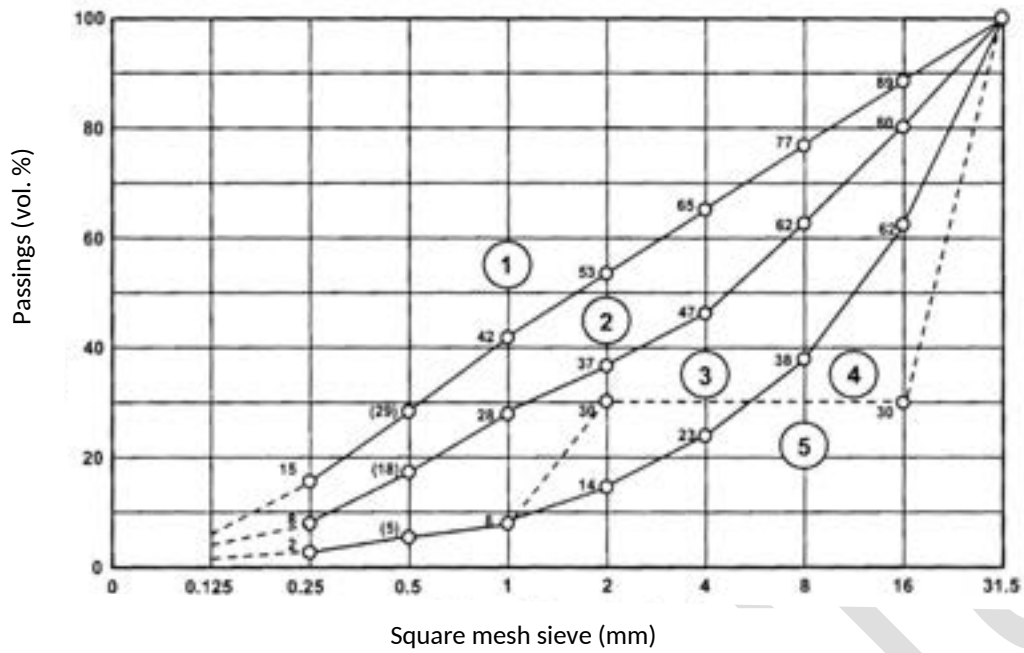
Figure C2. Granulometric zones for the maximum aggregate size of 16 mm



Key

- ① unfavourable
- ② usable
- ③ favourable
- ④ favourable for discontinuous granulometric composition
- ⑤ unfavourable

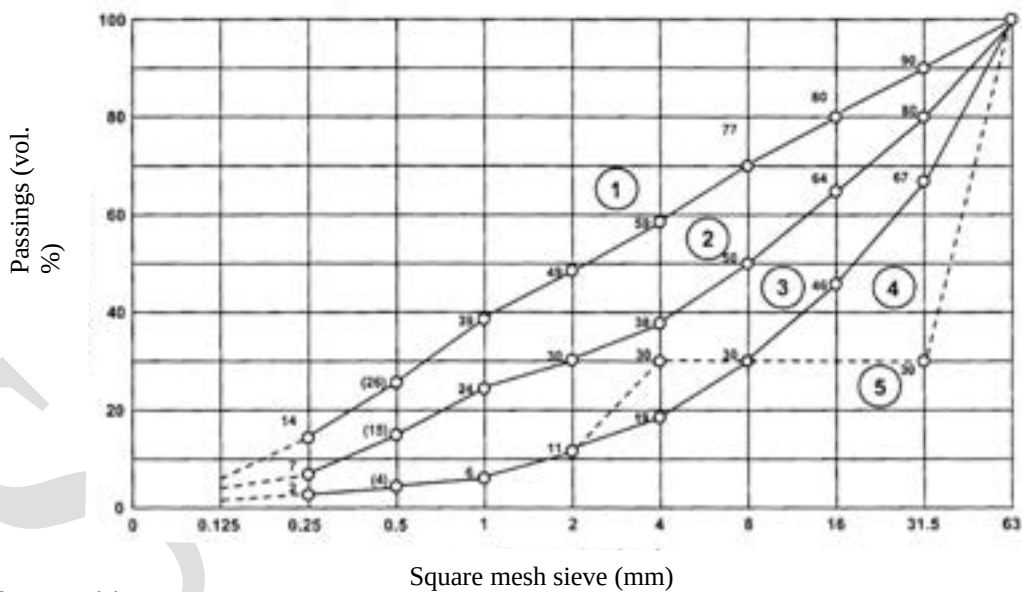
Figure C3. Granulometric zones for the maximum aggregate size of 22.4 (22) mm



Key:

- ① unfavourable
- ② usable
- ③ favourable
- ④ favourable for discontinuous granulometric composition
- ⑤ unfavourable

Figure C4. Granulometric zones for the maximum aggregate size of 31.5 (32) mm



Key:

- ① unfavourable
- ② usable
- ③ favourable
- ④ favourable for discontinuous granulometric composition
- ⑤ unfavourable

Figure C5. Granulometric zones for the maximum aggregate size of 63 mm

Annex D

(normative)

Values for concrete composition limits

(1) This Annex provides the limit values for the composition and properties of concrete according to the exposure class according to 4.2.1.4.

(2) Tables D1.1 and D1.2 show the limit values for the composition and properties of concrete by exposure class based on the assumption of a 50-year design working life and maintenance of the structure. The values in Tables D1.1 and D1.2 correspond to the different types of cements and aggregates where the maximum dimensions are between 20 and 31.5 (32) mm.

(3) Tables D2.1 and D2.2 show areas and examples of the use of cements manufactured according to SR EN 197-1 and SR EN 197-5 for different exposure classes.

(4) For the extension of the fields of application of cements or their establishment, the provisions of Annex J to NE 012/1 shall apply. For other cements not included in SR EN 197-1, the general suitability for use is based on the provisions of other European cement standards in force, regarding the design and execution of works, national standards developed taking into account recognised principles and procedures that comply with this Regulation. For all cements for which there is no experience in concrete use in the country, their introduction into regulations will be made only based on the results of experimental research conducted in independent authorised laboratories demonstrating the behaviour of concretes in response to different types of physico-mechanical and environmental demands, in accordance with this Regulation.

(5) Tables D3.1 and D3.2 provide the maximum permitted content of fine particles in prepared concrete with aggregates of different maximum grain sizes D_{\max} .

Table D1.1. Limit values for concrete composition and properties for exposure classes X0, XC, XD and XS

	Exposure classes										
	No risk of corrosion or chemical attack	Carbonation induced corrosion of reinforcing steel				Corrosion of concrete steel due to chlorides					
		X0	XC1	XC2	XC3	XC4	Chlorides from sources other than seawater			Chlorides from seawater	
						XD1	XD2	XD3	XS1	XS2	XS3
Maximum water/cement ratio ^a	-	0.65	0.60	0.55	0.50	0.55	0.50	0.45	0.50	0.45	0.45
Minimum resistance class	C12/15 ^b	C20/25	C25/30	C30/37	C30/37	C30/37	C30/37	C35/45	C35/45	C35/45	C35/45
Minimum cement dosage (kg/m ³)	-	260	280	280	300	300	300 ^a	320 ^a	300	320 ^a	340 ^a
Minimum entrained air content (%)	-	-	-	-	-	-	-	-	-	-	-
Other conditions	-	-	-	-	-	-	-	-	-	-	-

^a) Effective water is considered here (see definition given in SR EN 206+A2:2021 in section 3.1.3.4). When the k-value concept is applied, the maximum water/cement ratio and the minimum cement dosage shall be changed in accordance with 5.2.5.2 of SR EN 206+A2:2021

^b) In the case of plain concrete elements

NOTE: For precast products, in the case of semi-dry or low compaction concrete with aggregates ≥ 16 mm, it is permissible to reduce the cement dosage by up to 10 %, subject to checking compliance with the performance requirements specified in the product standards.

Table D1.2. Limit values for concrete composition and properties for exposure classes XF, XA and XM

	Exposure classes												
	Freeze-thaw attack						Chemical attack			Mechanical attack			
	XF1	XF2		XF3		XF4	XA1	XA2 ^c	XA3 ^c	XM1	XM2		XM3
Maximum water/cement ratio ^e	0.50	0.55	0.50	0.50	0.50	0.45	0.55	0.50	0.45	0.55	0.55	0.45	0.45
Minimum resistance class	C30/37	C30/37	C35/45	C30/37	C35/45	C30/37	C30/37	C35/45	C35/45	C30/37	C30/37	C35/45	C35/45
Minimum cement dosage (kg/m ³)	300	300	320	320	320	340 ^d	300	320	360	300	300	320	320
Minimum entrained air content (%)	-	4.0 ^a	-	4.0 ^a	-	4.0 ^a	-	-	-	-	-	-	-
Other conditions	Freeze-thaw resistant aggregates according to SR EN 12620, SR EN 1367-1 and SR EN 1367-2						Sulphate-resistant cement			Concrete surface treatment ^b			

^{a)} The entrained air content shall be determined according to the maximum grain size in accordance with 4.2.1.6. If the concrete does not contain intentionally entrained air, then the performance of the concrete shall be measured according to an appropriate test method compared to a concrete for which frost-thaw resistance has been established for the corresponding exposure class.

^{b)} Using methods that give the surface superior waterproofing/duration properties, e.g. vacuum treatment.

^{c)} When the presence of SO₄²⁻ leads to an exposure class of XA2 and XA3, it is essential to use a sulphate-resistant cement (see also Tables D2.1, D2.2).

^{d)} In the case of exposure in marine areas, cements resistant to the action of seawater are used (specific combinations of exposure classes).

^{e)} Effective water is considered here (see definition given in Article 3.1.16). When the k-value concept is applied, the maximum water/cement ratio and the minimum cement dosage shall be changed in accordance with 5.2.5.2 of SR EN 206+A2:2021

NOTE: For precast products, in the case of semi-dry or low compaction concrete with aggregates ≥ 16 mm, it is permissible to reduce the cement dosage by up to 10 %, subject to checking compliance with the performance requirements specified in the product standards.

Table D2.1. Fields of application for cements according to Standards SR EN 197-1 and SR EN 206+A2:2021^a and Regulation NE012/1

Cement type			Exposure classes											
			No risk of corrosion or chemical attack	Carbonation induced corrosion of reinforcing steel				Corrosion of concrete steel due to chlorides						
								Chlorides from sources other than seawater			Chlorides from seawater			
			XO	XC1	XC2	XC3	XC4	XD1	XD2	XD3	XS1	XS2	XS3	
CEM I			X	X	X	X	X	X	X	X	X	X	X	X
CEM II	A/B	S	X	X	X	X	X	X	X	X	X	X	X	X
	A/B	V	X	X	X	X	X	X	X	X	X	X	X	X
	A	LL	X	X	X	X	X	X	X	X	X	X	X	X
	B		X	X	X	O	O	O	O	O	O	O	O	O
	A	L	X	X	X	X	X	X	X	X	X	X	X	X
	B		X	X	X	O	O	O	O	O	O	O	O	O
	A	M	To be used in accordance with the provisions of Table D2.2											
B	To be used in accordance with the provisions of Table D2.2													
CEM III	A		X	X	X	X	X	X	X	X	X	X	X	X
CEM III	B ^e		X	O	O	O	O	O	O	O	O	O	O	O
CEM III	C ^e		X	O	O	O	O	O	O	O	O	O	O	O

Table D2.1 (continued) ^a

Cement type			Exposure classes									
			Freeze-thaw attack				Chemical attack			Mechanical attack		
			XF1	XF2	XF3	XF4	XA1	XA2 ^c	XA3 ^c	XM1	XM2	XM3
CEM I			X	X	X	X	X	X	X	X	X	X
CEM II	A/B	S	X	X	X	X	X	X	X	X	X	X
	A	V	X	X	X	X	X	X	X	X	X	X
	B		O	O	O	O	X	X	X	X	X	X
	A	LL	X	X	X	X	X	X	X	X	X	X
	B		O	O	O	O	O	O	O	O	O	O
	A	L	O	O	O	O	X	X	X	X	X	X
	B		O	O	O	O	O	O	O	O	O	O
	A	M	To be used in accordance with the provisions of Table D2.2									
B	To be used in accordance with the provisions of Table D2.2											
CEM III	A		X	X	X	X ^b	X	X ^d	X ^d	X	X	X
CEM III	B ^e		O	O	O	O	O	O	O	O	O	O

X Can be applied.

O Not applicable (due to lack of national experience).

^{a)} This table shows the areas of use of cements manufactured in accordance with SR EN 197-1. The conditions of use of cements are given in 4.1.2.

^{b)} CEM III/A with resistance class ≥ 42.5 with a quantity of slag ≤ 50 % by mass, excluding gypsum, shall be used where satisfactory performance has been demonstrated in response to freeze-thaw actions and deicing agents or seawater/salt lakes.

^{c)} When the presence of SO_4^{2-} leads to an exposure class of XA2 and XA3, it is essential to use a sulphate-resistant cement defined in accordance with SR EN 197-1

^{d)} May be applied, based on demonstration of performance in accordance with normative Annex J to NE 012/1

^{e)} May be applied, for certain exposure classes, based on demonstration of performance in accordance with Annex (normative) J to NE 012/1

Note 1: For the manufacture of precast elements and products, the provisions of Table 4.1 of this Regulation shall be taken into account.

Note 2: Only CEM I and CEM II/A cements shall be used for the production of precast prestressed concrete elements, provided that the concrete has demonstrated satisfactory behaviour in terms of strength, instantaneous deformation, shrinkage and creep.

Table D2.2. Fields of application for CEM II M, IV, V and VI type cements according to Standards SR EN 197-1 and SR EN 197-5

Cement type				Exposure classes										
				No risk of corrosion or chemical attack	Carbonation induced corrosion of reinforcing steel				Corrosion of concrete steel due to chlorides					
									Chlorides from sources other than seawater			Chlorides from seawater		
					XO	XC1	XC2	XC3	XC4	XD1	XD2	XD3	XS1	XS2
CEM II	M	A	S-LL	X	X	X	X	X	X	X	X	X	X	X
			S-V; V-LL	X	X	X	X	X	X	X	X	X	X	X
CEM II	M	B	S-V	X	X	X	X	X	X	X	X	X	X	X
			S-LL; V-LL	X	X	X	C	C	C	O	O	O	O	O
CEM II	M	B	S-V-LL	X	C	C	O	O	O	O	O	O	O	O
CEM II	M	C ^b	S-V; S-LL; V-LL	X	O	O	O	O	O	O	O	O	O	O
CEM IVA ^b				X	O	O	O	O	O	O	O	O	O	O
CEM IVB ^b				X	O	O	O	O	O	O	O	O	O	O
CEM VA ^b				X	O	O	O	O	O	O	O	O	O	O
CEM VB ^b				X	O	O	O	O	O	O	O	O	O	O
CEM VI ^b			S-V; S-LL; V-LL	X	O	O	O	O	O	O	O	O	O	O

SECOND

Table D2.2. (continued)

Cement type				Exposure classes										
				Freeze-thaw attack				Chemical attack			Mechanical attack			
				XF1	XF2	XF3	XF4	XA1	XA2 ^a	XA3 ^a	XM1	XM2	XM3	
CEM II	M	A	S-LL	X	X	X	X	X	X	X	X	X	X	
			S-V; V-LL	X	C	X	C	X	X	X	X	X	X	X
		B	S-V	X	C	C	C	X	X	X	X	X	X	X
			S-LL; V-LL	C ^e	C ^e	C ^{c; e}	C ^{d; e}	O	O	O	X	O	O	O
CEM II	M	B	S-V-LL	C ^{c; e}	C ^{c; e}	O	O	O	O	O	O	O	O	
CEM II	M	C ^b	S-V; S-LL; V-LL	O	O	O	O	O	O	O	O	O	O	
CEM IVA ^b				O	O	O	O	O	O	O	O	O	O	
CEM IVB ^b				O	O	O	O	X	X	X	O	O	O	
CEM VA ^b				O	O	O	O	O	O	O	O	O	O	
CEM VB ^b				O	O	O	O	O	O	O	O	O	O	
CEM VI ^b			S-V; S-LL; V-LL	O	O	O	O	O	O	O	O	O	O	

X Can be applied;
O Not applicable (due to lack of national experience)
C Application subject to demonstration of performance according to normative Annex J to NE 012/1.
^{a)} When the presence of SO₄²⁻ leads to an exposure class of XA2 and XA3, it is essential to use a sulphate-resistant cement defined in accordance with SR EN 197-1
^{b)} May be applied for other exposure classes based on demonstration of performance in accordance with Annex (normative) J to NE 012/1
^{c)} Can be applied for air entrained concrete
^{d)} For specific applications the concrete surface is treated by coating with protective film or mechanical sanding in accordance with CD 139
^{e)} They may be used based on the performance in accordance with Annex (normative) J to NE 012/1. If the percentage of limestone (excluding gypsum) exceeds 15 % LL, the cements must meet all of the performance criteria for freeze-thaw resistance (applicable slab test and cube test methods).

Note 1: For the manufacture of precast elements and products, the provisions of Table 4.1 of this Regulation shall be taken into account.

Note 2: If other types of cement manufactured in accordance with SR EN 197-1, SR EN 197-5 and SR EN 197-6 are used, the areas of use for precast products shall be established on the basis of demonstration of performance in accordance with normative Annex J to NE 012/1.

Table D3.1. Maximum permissible fine particle content in concrete prepared with aggregates with a maximum grain size D_{max} of 16 mm to 63 mm for concrete class \leq C50/60 and LC \leq 50/55

Cement dosage (kg/m³)	Maximum fine particle content (kg/m³) < 0.125 mm
≤ 300	400
300 ... 400	550
≥ 400	600

Table D3.2. Maximum permissible fine particle content in concrete prepared with aggregates with a maximum grain size D_{max} of 16 mm to 63 mm for concrete class $>$ C50/60 and LC $>$ 50/55

Cement dosage (kg/m³)	Maximum fine particle content (kg/m³) < 0.125 mm
≤ 400	500
400 ... 450	Cement dosage + 100
450 ... 500	Cement dosage + 100
≥ 500	600

Note: Fine particle content refers to the contribution made by each of the solid components of concrete (cement, aggregates, additions) with a particle size $<$ 0.125 mm.

ANNEX E

(normative)

Classes for fresh concrete

E1. Consistency classes

(1) Tables E1, E2, E3 and E4 apply when concrete is classified according to its consistency. In the case of self-compacting concrete, only the classes in Table E4 apply.

(2) The consistency may also be specified by a target value with the tolerances indicated in Table 23 in SR EN 206+A2:2021.

Note 1: There is no direct relationship between the consistency classes in Tables E1 to E4. For semi-dry concrete, i.e. concrete with a low water content, designed to be compacted using a special process, the consistency is not classified. For this type of concrete, the consistency can be specified by means of the VE-BE test in accordance with SR EN 12350-3.

Table E1. Slump classes

Class	Slump, test in accordance with SR EN 12350-2 (mm)
S1	from 10 to 40
S2	from 50 to 90
S3	from 100 to 150
S4	from 160 to 210
S5 ^a	≥ 220

^{a)} See Note 1 to Article 5.4.1 of SR EN 206+A2:2021.

Table E2. Compaction classes

Class	Compaction index, test in accordance with SR EN 12350-4
C0 ^a	≥ 1.46
C1	from 1.45 to 1.26
C2	from 1.25 to 1.11
C3	from 1.10 to 1.04
C4 ^b	< 1.04

^{a)} See Note 1 to Article 5.4.1 of SR EN 206+A2:2021
^{b)} C4 applies only to lightweight concrete

Table E3. Spread classes

Class	Spread diameter, test in accordance with SR EN 12350-5 (mm)
F1 ^a	≤ 340
F2	from 350 to 410
F3	from 420 to 480
F4	from 490 to 550
F5	from 560 to 620
F6 ^a	≥ 630

^{a)} See Note 1 to Article 5.4.1 of SR EN 206+A2:2021

Table E4. Slump flow classes

Class	Spread ^a , test in accordance with SR EN 12350-8 (mm)
SF1	from 550 to 650
SF2	from 660 to 750
SF3	from 760 to 850
^{a)} The classification does not apply to concrete with a D_{max} greater than 40 mm	

E2. Classes of additional properties of self-compacting concrete

(1) When self-compacting concrete is classified according to its viscosity, passing ability or segregation resistance (sieve stability test), Tables E5 to E9 apply.

(2) The apparent viscosity may also be specified as a target value, with the tolerances in Table 23 in SR EN 206+A2:2021.

(3) The passing ability may also be specified as a minimum value when the test is carried out using the L box method, or as a maximum value when determined using the J-ring method.

(4) Segregation resistance may also be specified as a maximum value.

Table E5. Viscosity classes - t_{500}

Class	t_{500} ^a , test in accordance with SR EN 12350-8 (s)
VS1	< 2.0
VS2	≥ 2.0
^{a)} The classification does not apply to concrete with a D_{max} greater than 40 mm	

Table E6. Apparent viscosity classes - t_v

Class	t_v ^a , test in accordance with SR EN 12350-9 (s)
VF1	< 9.0
VF2	from 9.0 to 25.0
^{a)} The classification does not apply to concrete with a D_{max} greater than 22.4 mm	

Note 1: The classes defined in Tables E5 and E6 are similar, but not exactly correlated.

Table E7. Passing ability classes - L-box

Class	L box filling coefficient, test in accordance with SR EN 12350-10
PL1	≥ 0.80 with 2 reinforcements
PL2	≥ 0.80 with 3 reinforcements

Table E8. Passing ability classes - J-Ring

Class	J-ring bar spacing ^a , test in accordance with SR EN 12350-12 (mm)
PJ1	≤ 10 with 12 reinforcements
PJ2	≤ 10 with 16 reinforcements
^{a)} The classification does not apply to concrete with a maximum aggregate size greater than 40 mm	

Note 2: The classes defined in Tables E7 and E8 are similar, but not exactly correlated.

Table E9. Segregation resistance classes

Class	Segregated portion ^a , test in accordance with SR EN 12350-11 (%)
SR1	≤ 20
SR2	≤ 15
^{a)} The classification does not apply to concrete with a D_{max} greater than 40 mm	

ANNEX F

(normative)

Strength classes for hardened concrete

F1. Strength classes for normal density and heavy concretes

Compressive strength

(1) Characteristic compressive strength at 28 days, measured on cylinders with a diameter of 150 mm and a height ($f_{ck,cyl}$) of 300 mm, or characteristic compressive strength at 28 days, measured on cubes with a side length of 150 mm ($f_{ck,cub}$), in accordance with SR EN 12390-3.

(2) The tests may also be carried out after the 28-day term, up until 91 days, in accordance with the provisions of the design, which will specify the time limit, the purpose and the manner of interpreting the results of these tests, in order to define the compressive strength class in accordance with SR EN 1992-1-1.

Table F1.1. Compressive strength classes for normal density and heavy concretes

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

Table F1.2. Compressive strength classes for lightweight concretes

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

^(a) Other values may be used if their relationship to strength on cylinders is established and documented.

F2. Strength and ductility classes for steel fibre reinforced concrete

(1) The characteristic residual strengths $f_{R,1k}$ and $f_{R,3k}$ for steel fibre reinforced concrete shall be determined in accordance with SR EN 14651. These must be classified both in strength classes SC (1.0; 1.5; 2.0; 2.5; 3.0; 3.5; 4.0; 4.5; 5.0; 6.0; 7.0; 8.0) and in ductility classes (a) to (e), in accordance with Table F2.

Note 1: The classification is made in accordance with the values $f_{R,1k}$ and $f_{R,3k}$. The strength class is selected by comparing the value of $f_{R,1k}$, determined experimentally, with the limits defining the strength classes specified in brackets. The ductility class, designated by a letter, is selected by comparing $f_{R,3k}$, determined experimentally, with the values in Table F2.

Note 2: $f_{R,1k}$ and $f_{R,3k}$, which will be used for design purposes, correspond to the values obtained according to the classification in the strength class and ductility class respectively, in accordance with Table F2.

Table F2. Strength and ductility classes for steel fibre reinforced concrete (MPa)

Ductility classes	Strength classes SC ($f_{R,1k} \geq SC$)												Analytical relationships
	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	6.0	7.0	8.0	
a	0.5	0.8	1.0	1.3	1.5	1.8	2.0	2.3	2.5	3.0	3.5	4.0	$f_{R,3k} \geq 0.5SC$
b	0.7	1.1	1.4	1.8	2.1	2.5	2.8	3.2	3.5	4.2	4.9	5.6	$f_{R,3k} \geq 0.7SC$
c	0.9	1.4	1.8	2.3	2.7	3.2	3.6	4.1	4.5	5.4	6.3	7.2	$f_{R,3k} \geq 0.9SC$
d	1.1	1.7	2.2	2.8	3.3	3.9	4.4	5.0	5.5	6.6	7.7	8.8	$f_{R,3k} \geq 1.1SC$
e	1.3	2.0	2.6	3.3	3.9	4.6	5.2	5.9	6.5	7.8	9.1	10.4	$f_{R,3k} \geq 1.3SC$

Annex G

(informative)

Assessment of the compressive strength of concrete by application of the maturity method

G1. General considerations

- (1) This Annex presents the manner of assessing the strength of concrete by applying the maturity method described in accordance with ASTM C 1074.
- (2) This method involves establishing in the laboratory the relationship between compressive strength, maturity factor/index and time for a given concrete mix composition (calibration of the mix design). By recording the changing temperature of the concrete in the element under assessment (from the construction site or manufacturing hall), the compressive strength can be evaluated over time, at certain intervals.
- (3) The method can be used to assess the compressive strength of concrete in precast elements, including for determining the timing of specific technological phases such as: formwork removal, cutting of pretensioned cables or post-tensioning of cables, transport to the storage area, loading of elements onto transport vehicles, etc.

G2. Description of method

- (1) After calibration of the mix composition, the method consists in recording the changing temperature and calculating the index/maturity factor of the concrete in the element subject to strength assessment from the time the concrete is poured until the prescribed level (of the maturity index/factor) is reached for compressive strength (as a threshold required to be achieved for certain stages in the execution of the element).
- (2) The temperature history in the element is recorded and converted into the concrete maturity index/factor, depending on the monitoring equipment used, by applying the NURSE-SAUL or ARRHENIUS maturity relationship/function.
- (3) To calculate the maturity index/factor, knowing the history of the measured concrete temperature, one of the following two functions can be applied: NURSE-SAUL or ARRHENIUS. In practical terms, the NURSE-SAUL function, detailed in this Annex, is simpler and more frequently used (corresponding to a large number of applications) but the ARRHENIUS function is more precise:
 - i. The NURSE-SAUL maturity function can be used to calculate the temperature-time factor (maturity index/factor, M_{NS}) by applying relation G1, considering the development of concrete strength as a linear function of temperature:

$$M_{NS} = \sum (T_{a,n} - T_0) \cdot \Delta t \quad (G1)$$

where:

- M_{NS} = temperature-time factor (index/maturity factor) at age t, in °C-days or °C-hours;
- Δt = time interval, in days or hours;
- $T_{a,n}$ = average concrete temperature over the time interval Δt , in °C;
- T_0 = reference temperature, in °C.

(4) The maturity index/factor, expressed as a temperature-time factor in °C-days or °C-hours, is represented graphically as an area, as shown in Figure G1. For temperature values below the reference temperature (T_0), the corresponding area is not taken into account.

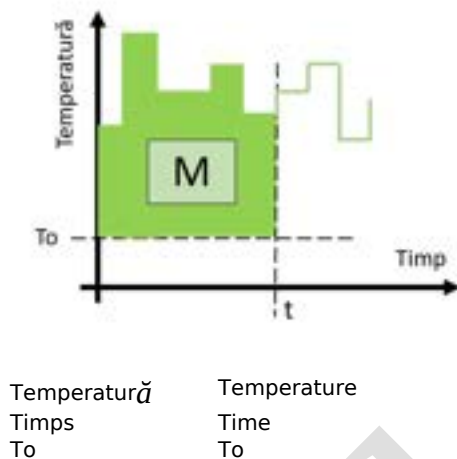


Figure G1. Maturity index/factor expressed as a temperature-time factor in °C-days or °C-hours

(5) By applying the maturity method using the NURSE-SAUL maturity function, the aim is to establish a linear relationship between the maturity index/factor ' M_{NS} ' and the compressive strength of concrete so that the compressive strength of the concrete can be established at any time after pouring, based on the progression of the maturity index/factor ' M_{NS} ' at the construction site (Figure G2).

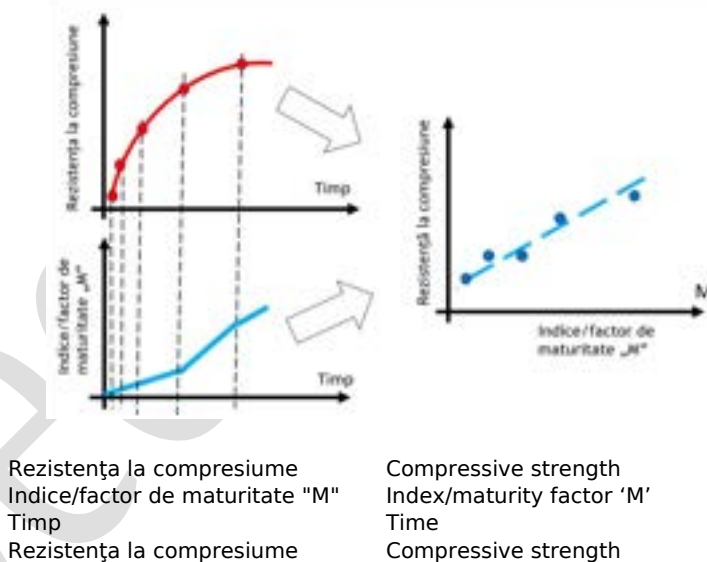


Figure G2. Establishing the linear relationship between the maturity index/factor ' M_{NS} ' and the compressive strength of the concrete

ii. The ARRHENIUS maturity function can be used to calculate the equivalent age, t_e at a specified temperature by applying the G2 relationship, considering the development of strength as an exponential function of temperature:

$$t_e = \sum e^{-Q \left(\frac{1}{T_{a,a}} - \frac{1}{T_s} \right)} \Delta t \quad (G2)$$

where:

1. t_e = equivalent age of concrete at the reference temperature, T_s in days or hours;
2. $Q = E/R$ is the ratio between the activation energy E and the universal gas constant R , equal to 8,314 J/mol-K, in Kelvin;
3. $T_{a,a}$ = mean concrete temperature over the time interval Δt , in Kelvin;
4. T_s = reference temperature, in Kelvin;
5. Δt = time interval, in days or hours;

(5) The index/maturity factor MA is expressed as the equivalent age (t_e) of the concrete at the reference temperature (T_s).

(6) Equipment for measuring the index/maturity factor may include the application of one or both of these functions (NURSE-SAUL/ARRHENIUS). If both functions are available, the same function shall be used when calibrating the mix composition (carrying out the initial testing), when monitoring the calibration (conducting continuous testing), and when recalibrating, if applicable.

(7) The temperature measurements taken from the precast concrete element shall be performed throughout application of the method using the same type of sensors, since changing the type of sensors will require additional checks of the accuracy of the mathematical relationships established and applied.

(8) After laboratory calibration of the concrete composition to be used, the data (maturity index/factor and other required data) are entered into the calculation programme of the equipment used, thus allowing for indirect assessment, on the construction site or in the manufacturing hall, of the compressive strength of the concrete in the precast element.

(9) The accuracy with which the compressive strength is assessed depends primarily on how the mix composition is calibrated in the laboratory (initial testing) and on the level of detail involved. The greater the number of intervals at which (frequency with which) the tests are performed (especially in the short-term) and the more varied and controlled the environmental conditions under which the samples are stored, the more accurate the estimation of strength [based on] the maturity index/factor will be.

G3. Requirements regarding equipment

(1) The monitoring equipment (sensors) that records the time-temperature history of the concrete on the construction site or in the production hall and calculates the maturity index/factor, according to equations G1 or G2, shall ensure consistency with the records made during calibration (initial laboratory testing), calibration monitoring (continuous testing) and recalibration of the concrete mix, where applicable.

(2) In order to monitor the progress of essential parameters, the equipment's software shall provide real-time graphs of the temperature, maturity index/factor, maturity and compressive strength of the concrete in the precast element. It is recommended that specific electronic and written records be obtained and archived for each concrete mix and precast element, identified separately.

(3) It is recommended that the interval between temperature recordings during application of this method be no more than 15 min. The temperature recording device must have an accuracy of maximum ± 1 °C.

G4. Procedure for calibrating the concrete mix in the laboratory (initial testing), continuous testing and recalibration

(1) It is recommended that compressive strength tests be carried out in the laboratory at least 5 times using a minimum of 15 test specimens (constituting a set), usually cubic. The materials and proportions of the concrete mix used to prepare the samples must be the same as for the concrete used (on the construction site or in the production hall) to manufacture the precast element whose compressive strength is to be assessed. If two batches of concrete are required to ensure the necessary number of specimens/sets, it is recommended that an equal number of specimens be made from each batch and that at least one specimen from each batch be tested at the same time for comparison purposes. Choose the function (NURSE-SAUL or ARRHENIUS) with which the maturity method will be applied.

(2) Once the test specimens (the set) have been cast, temperature sensors/thermocouples are inserted into the centre of at least two cubes. After inserting the sensor, gently tap the side of the formwork with a rubber mallet or tamping rod so that the fresh concrete comes into contact with the sensor, then connect the sensors to equipment meeting the requirements set out in Article G3.

(3) Two sets of concrete test specimens shall be cast. One set shall be stored under controlled laboratory conditions (temperature (20 ± 2) °C and humidity of 65 %) and the other set under temperature and humidity conditions similar to the actual conditions to which the precast element to be monitored is exposed (on the construction site or in the manufacturing hall).

(4) The intervals at which the specimens of both sets are tested shall be the same and be established for calibration according to the stages for which the compressive strength is to be monitored (formwork removal, transfer, delivery, etc.). The test shall be carried out at least five intervals, ensuring that information is obtained especially for short intervals (up to seven days).

(5) In order to define as accurately as possible the relationship between compressive strength and the maturity index/factor, it is recommended that the strength testing intervals for the laboratory test set be more frequent in the initial period after casting, i.e. at 6, 12, 18, 24, 36, 48, 72 hours, etc., depending on requirements, especially for prestressed concrete with pretensioned reinforcement.

(6) The temperature must be recorded sufficiently often on the premises in which the sets of samples are kept that there is a good assessment of the thermal history prior to calculation of the index/maturity factor.

(7) At least two samples shall be tested at each interval and the mean compressive strength shall be calculated. If the difference between one of the individual compressive strength values of the two samples and the mean value of both is greater than 10 % of the calculated mean compressive strength, a third cube shall be tested and the mean of the three results calculated. If it is found that one of the values obtained is due to a sample that shows obvious visual defects, the corresponding result shall be excluded from calculation of the mean.

(8) Given the rapid development of compressive strength, the first test interval shall be set as close as possible to the moment of final setting of the concrete. The moment of final hardening of the concrete can be determined visually, with a penetrometer or by non-destructive methods.

(9) At each interval the time of the test and the age of the concrete shall be recorded and the index/maturity factor of the concrete calculated and recorded.

(10) Using the NURSE-SAUL maturity function, the maturity index/factor 'MNS' is expressed as a temperature-time factor and, using the ARRHENIUS maturity function, the maturity index/factor 'MA' is expressed as the equivalent age of the concrete at the reference temperature.

(11) The specialised temperature monitoring equipment, as a rule, also measures the ambient temperature as well as calculating the maturity of the concrete.

(12) Based on the information obtained for each set of samples (those kept in the laboratory and those under real conditions), the development of compressive strength as a function of the maturity index/factor is represented graphically and compared in the laboratory and under real conditions.

(13) Monitoring the calibration of a concrete mix (or performing continuous testing) means checking over time (e.g. for a minimum of 15 intervals, a number of values that can provide statistical processing) and under real conditions (on the construction site) of the correctness of the relationship established between strength and time.

(14) Checking can be carried out on a smaller number of concrete samples, usually cuboid, tested destructively only within the time limits relevant to the technological process.

(15) A concrete mix is recalibrated (initial retesting) when the composition is changed, with the aim of re-establishing/reconfirming and monitoring (continuous retesting) the relationship between the strength of the concrete whose composition has changed and time.

(16) Special attention shall be paid to how the strength-maturity relationship is established, calibration of the concrete mix, calibration monitoring and re-calibration in all situations, with responsibility, based on a working procedure, especially in the case of prestressed concrete with pretensioned reinforcement.

G5. Procedure for assessing the strength of precast elements (on the construction site or in the manufacturing hall)

(1) The relationship between compressive strength and index/maturity factor or equivalent age at the reference temperature, as appropriate, for the concrete composition to be used is calibrated.

(2) Temperature sensors (thermocouples) are placed inside the element to be constructed, before pouring the concrete, in the areas selected (by design, with the designer's approval) to determine the maximum temperature, as well as in other positions relevant to the respective elements (e.g. near the surface of the element), in order to obtain information about the temperature differences between the interior of the element and its surface, as well as between the surface of the element and the environment. The ambient temperature in the immediate vicinity of the concrete is continuously monitored throughout the period of application of the method.

(3) Temperature sensors are placed so that they are completely embedded in concrete and not in direct contact with reinforcement bars or other metal elements. The recommendations of the monitoring equipment manufacturer shall also be taken into account.

(4) After connecting the sensors to the equipment for determining the maturity, the parameters for calibration of the concrete mix are programmed into the equipment.

(5) To assess the strength of concrete in precast elements with relatively similar values for the three dimensions, it is recommended to use several temperature measurement points in the element.

(6) Before performing operations such as transfer, removal of formwork, cutting of pretensioned or post-tensioning reinforcements, or whenever specified in the plan, it is also recommended that concrete samples be tested as part of the initial and continuous testing process.

G6. Final considerations

(1) The maturity method is used to estimate the strength of concrete in precast elements, taking into account the differences between the compressive strength of the sampled cubes and that of the element in question (due primarily to the various dimensions that influence the development of compressive strength through differences in heat release).

(2) The accuracy of the estimated compressive strength depends on several factors, such as the way in which the concrete mix was calibrated, changes in the quality of the component materials of the concrete and their dosage, etc.

ANNEX H

(informative)

Application of non-destructive (indirect) methods

H1. Correlation between results obtained destructively and non-destructively

(1) It is recommended that non-destructive tests or, as they are generally referred to in SR EN 13791, indirect tests, be carried out before extracting cores. The results obtained will be used to locate the zones from which the cores should be extracted. It is recommended that at least 10 pairs of test results be obtained and that the cores cover the entire range of results obtained by applying indirect tests, including the extremes. The results obtained from the core samples shall be used to obtain in situ compressive strengths ($f_{c, is}$) and the results obtained by applying indirect tests shall be plotted as values on the X axis, while the results obtained from the core samples and representing the strengths $f_{c, is}$ shall be plotted on the Y axis. The best linear regression through the points obtained will be considered and analysed as reasonable for the concrete being assessed (type, age, etc.). SR EN 13791 specifies that in order to develop a proper relationship, 8 pairs of results are also sufficient, and the recommendation to use 10 results stems from the fact that certain results may lie outside a valid range, taking into account specific Grubb-type analyses. Standard SR EN 13791 does not specify what is meant by adequate correlation, even though it primarily refers to it. However, some indications are given relating to determining the validity of the intervals associated with the linear regression equations. Thus, when determining the values resulting from the regression equations, they shall not be extrapolated beyond 4 MPa at either end of the demonstrated relationship.

(2) The regression equations can be used to estimate compressive strength by applying indirect methods, but can also be used to estimate strength in a given test zone as will be presented below.

H2. Estimation of the characteristic in-situ strength for a given test zone

(1) The mean compressive strength is calculated using the following formula:

$$f_{c, m(m)is} = \Sigma(f_{c, is, reg}) / m \quad (H1)$$

(2) The standard deviation of the in-situ strength of the test zone is determined by applying the formula:

$$s = \sqrt{s_c^2 + s_e^2} \quad (H2)$$

Where:

$$s_e = \sqrt{\frac{\sum_{i=1}^m (f_{c, is, reg} - f_{c, m(m)is})^2}{m - 1}} \quad (H3)$$

and

$$s_c = \sqrt{\frac{\sum_{i=1}^n (f_{c, is} - f_{c, is, reg})^2}{n - 2}} \quad (H4)$$

where:

s_{c_c} – the residual standard deviation, which is a measure of the spread of strengths obtained from cores around the regression curve

s_e – the standard deviation of all strength values, which is a measure of the spread of core strengths around the mean value

n – the number of result pairs used to establish the calibration curve

m – the number of values for the estimated strengths.

NOTE: The formulas are only valid when the correlation has two parameters, for example ($y = a + b \cdot x$) or ($\ln y = a + b \cdot \ln x$). In other cases, the term ($n - 2$) is replaced by ($n - p$), where p is the number of parameters in the formula. The value of s_c that is taken into account shall be the calculated value or 2 MPa, whichever is the greater.

(3) The effective number of degrees of freedom associated with the standard deviation s shall be calculated using the formula:

$$n_{\text{eff}} = \frac{\left[s_c^2 + s_e^2 \right]^2}{\frac{s_c^4}{n-2} + \frac{s_e^4}{m-1}} \quad (\text{H5})$$

(4) To estimate the characteristic strength, formulas (H6) and (H7) are used and, between the two, the lowest value obtained is taken into account:

$$f_{ck, is} = f_{c, m(n)is} - k_n s \quad (\text{H6})$$

$$f_{ck, is} = f_{c, is, lowest} + M \quad (\text{H7})$$

in which the value of k_n is determined based on the values in Table H1,

Table H1. Values of the coefficient k_n used in the formula (H6)

$n_{\text{eff}}+1$	8	10	12	16	20	30	∞
k_n	2.00	1.92	1.87	1.81	1.76	1.73	1.64

while the margin M is determined in accordance with Table H2.

Table H2. Value of the margin M used in the formula (H7)

Value $f_{c, is, lowest}$ (MPa)	Margin M (MPa)
≥ 20	4
$\geq 16 < 20$	3
$\geq 12 < 16$	2
< 12	1

H.3 Screening tests using a general or specific relationship with a procedure for applying an indirect test

(1) This method is generally only used to estimate the evenness of the concrete mix composition in a test area to determine, for example, the variability of strength, to identify areas of lower

strength and also to indicate whether or not the specified compressive strength of the concrete has been achieved; it must not be applied to determine the concrete strength class. Tables H3 and H4 present the relationships between the values of the rebound indices and the compressive strength classes.

(2) If the criteria set out in Tables H3 and H4 are not met, this does not automatically mean that the concrete is not within the prescribed strength class.

(3) There are various methods for establishing a relationship between concrete strength and the measured values of rebound indices or ultrasonic velocity. Such a procedure, taken from the German national annex to Standard EN 13791: 2006, is indicated in SR EN 13791. The rebound indices obtained for all test positions in the zone are used to determine the median of a test zone, considering the following conditions to have been met:

- the concrete is of normal weight;
- no controlled permeability formwork was used and the surface was not treated;
- Sclerometers with an impact energy of 2.207 Nm were used to measure the rebound distance (R), the energy difference or the velocity (Q);
- the minimum number of results obtained shall be 9, and the tests shall be carried out in accordance with SR EN 12504-2;
- the carbonation depth does not exceed 5 mm.

(4) Tables H3 and H4 present the proposals from Standard SR EN 13791.

Table H3. Rebound index based on the rebound distance (type R) associated with compressive strength in accordance with SR EN 206+A2:2021 for the strength classes of normal-weight concrete

Lowest value of the rebound index	Median of the rebound indices	Compressive strength class according to SR EN 206+A2:2021 ^a
≥ 26	≥ 30	C8/10
≥ 30	≥ 33	C12/15
≥ 32	≥ 35	C16/20
≥ 35	≥ 38	C20/25
≥ 37	≥ 40	C25/30
≥ 40	≥ 43	C30/37
≥ 44	≥ 47	C35/45
≥ 46	≥ 49	C40/50
≥ 48	≥ 51	C45/55
≥ 50	≥ 53	C50/60
≥ 53	≥ 57	C55/67
≥ 57	≥ 60	C60/75
≥ 62	≥ 65	C70/85
≥ 66	≥ 69	C80/95

Note ^(a) 90 % of results are above this value (10th percentile)

Table H4. Rebound index based on the energy or velocity difference (type Q) associated with compressive strength in accordance with SR EN 206+A2:2021 for the strength classes of normal-weight concrete

Lowest value of the rebound index	Median of the rebound indices	Compressive strength class according to SR EN 206+A2:2021 ^a
≥ 25	≥ 34	C8/10
≥ 29	≥ 40	C12/15
≥ 36	≥ 45	C16/20
≥ 42	≥ 49	C20/25
≥ 46	≥ 52	C25/30
≥ 51	≥ 56	C30/37
≥ 56	≥ 60	C35/45
≥ 58	≥ 62	C40/50
≥ 60	≥ 64	C45/55
≥ 62	≥ 66	C50/60
≥ 64	≥ 68	C55/67
≥ 66	≥ 71	C60/75
≥ 69	≥ 73	C70/85
≥ 71	≥ 75	C80/95

Note ^(a) 90 % of results are above this value (10th percentile)