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Eurocode — Basis of structural and geotechnical design — Part 1: New structures

Eurocode — Grundlagen der Tragwerksplanung und geotechnischen Bauwerken — Teil 1: Neue Tragwerken

Eurocode — Bases de calcul des structures et géotechniques —Partie 1: Nouveaux structures

ICS:

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European foreword

This document (prEN 1990-1:2024) has been prepared by Technical Committee CEN/TC 250 “Structural Eurocodes”, the secretariat of which is held by BSI. CEN/TC 250 is responsible for all Structural Eurocodes and has been assigned responsibility for structural and geotechnical design matters by CEN.

This document is an amendment to EN 1990:2023 and is currently submitted to the Enquiry.

The following main changes to EN 1990:2023 is included in the amendment:

— inclusion of application rules for:

— towers, masts and chimneys (Clause A.3);

— silos and tanks (Clause A.4);

— structures supporting cranes or other machines (Clause A.5);

— coastal structures (Clause A.6);

— inclusion of combination factors for new categories for imposed loads.

The first generation of EN Eurocodes was published between 2002 and 2007. This document forms part of the second generation of the Eurocodes, which have been prepared under Mandate M/515 issued to CEN by the European Commission and the European Free Trade Association.

The Eurocodes have been drafted to be used in conjunction with relevant execution, material, product and test standards, and to identify requirements for execution, materials, products and testing that are relied upon by the Eurocodes.

The Eurocodes recognise the responsibility of each Member State and have safeguarded their right to determine values related to regulatory safety matters at national level through the use of National An-nexes.

# Modification to the title

*Replace “*Eurocode — Basis of structural and geotechnical design*” with “*Eurocode — Basis of structural and geotechnical design — Part 1: New structures*”.*

# Modifications to the Introduction

*Replace subclause 0.2 with:*

*“***0.2 Introduction to EN 1990**

This document gives the principles and requirements for safety, serviceability, robustness, and durability of new structures and existing structures that are common to all Eurocodes parts and are to be applied when using them.

EN 1990 is subdivided in various parts:

EN 1990-1 *Eurocode — Basis of structural and geotechnical design — Part 1: New structures;*

EN 1990-2 *Eurocode — Basis of structural and geotechnical design — Part 2: Assessment of existing structures.”*

*Add a new subclause 0.3, then have the following subclauses automatically renumbered:*

“**0.3 Introduction to EN 1990-1**

This document gives the principles and requirements for safety, serviceability, robustness, and durability of new structures that are common to all Eurocodes parts and are to be applied when using them. This part can also be applied for existing structures, with the additional provisions given in prEN 1990-2.”

*In the new subclause 0.5, replace EN 1990 with EN 1990-1.*

*In the new subclause 0.5, replace the list “National choice is allowed in EN 1990-1 through notes to the following” with the following:*

|  |  |  |  |
| --- | --- | --- | --- |
| 4.1(4) | 4.2(4) | 4.3(1) | 4.4(2) |
| 4.7(1) | 6.1.3.2(4) – 3 choices | 6.1.3.2(6) | 7.1.5(7) |
| 8.3.2.1(4) | 8.3.3.1(5) | 8.3.3.6(1) | 8.3.4.2(2) – 2 choices |
| A.1.3(1) | A.1.4(1) | A.1.6.1(1) – 3 choices | A.1.6.3(1) |
| A.1.7(1) – 2 choices | A.1.8.1(1) | A.1.8.2.2(2) | A.1.8.2.3(2) |
| A.1.8.3(1) | A.1.8.3(3) | A.1.8.3(4) | A.1.8.4(2) |
| A.1.8.4(4) – 3 choices | A.2.3(1) | A.2.4(1) | A.2.7.1(1) – 3 choices |
| A.2.7.3.6(1) | A.2.7.4.1(1) – 2 choices | A.2.7.4.3(1) | A.2.7.4.5(1) |
| A.2.7.4.6(1) – 2 choices | A.2.7.5.1(1) | A.2.7.5.3(1) | A.2.7.5.4(1) – 2 choices |
| A.2.7.6.1(1) | A.2.7.6.4(1) | A.2.7.10(5) – 2 choices | A.2.7.10(9) |
| A.2.8(1) – 3 choices | A.2.9.1(1) | A.2.9.3.1(5) | A.2.9.3.3(1) |
| A.2.9.3.3(3) | A.2.9.3.3(4) | A.2.9.4.1(1) – 2 choices | A.2.9.4.2.1(3) |
| A.2.9.4.2.2(4) | A.2.9.4.2.2(5) | A.2.9.4.2.3(1) | A.2.9.4.2.3(2) |
| A.2.9.4.2.4(2) – 2 choices | A.2.9.4.2.4(4) | A.2.9.5(1) | A.2.10(1) |
| A.2.11.1(9) | A.2.11.4.5(3) | A.2.11.4.7(1) | A.3.2(1) |
| A.3.3(1) | A.3.5.1(1) – 4 choices | A.3.5.3(1) | A.3.6(1) – 2 choices |
| A.3.7.1(3) | A.3.7.4(3) | A.4.2.1(1) | A.4.2.1(2) |
| A.4.2.2(1) | A.4.2.2(2) | A.4.3.1(1) | A.4.3.1(3) |
| A.4.3.2(1) | A.4.5.1.1(1) – 2 choices | A.4.5.3(1) | A.4.5.3(2) |
| A.4.6(3) – 2 choices | A.4.6(4) | A.5.3(2) | A.5.4(1) |
| A.5.5.3(6) | A.5.6.2(1) | A.5.6.2(2) | A.5.6.4(1) |
| A.5.7.1(1) | A.5.7.1(6) | A.5.8(2) | A.6.3(1) |
| A.6.4(1) | A.6.6.1(1) – 3 choices | A.6.6.3(1) | A.6.7(1) – 2 choices |
| B.2(1) | B.4(2) | B.5(1) | B.6(1) |
| B.6(2) | B.7(1) | B.8(1) | C.3.1(5) |
| C.3.4.2(3) | D.4.1(1) | E.4(4) | G.2(1) |
| G.3.1(6) | G.3.3.2(1) | G.3.3.2(2) | G.3.4(2) |
| G.3.4(3) | G.6(2) | G.7.1.2(2) | G.7.1.3(2) |
| G.7.3.2(2) | G.7.4.2(1) | G.7.5.1(1) | G.7.5.2(1) – 2 choices |

# Modifications to 1.1, Scope of prEN 1990-1

*In the title of the Clause, replace EN 1990 with prEN 1990-1.*

*Add a new paragraph (2), then have the following subclauses automatically renumbered:*

“(2) This document is also applicable for existing structures, with the additional provisions given in prEN 1990-2.”

*Replace the new paragraph (3) and (4) with:*

“(3) This document is intended to be used in conjunction with the other Eurocodes for buildings and civil engineering works, including temporary structures.

(4) This document describes the basis for structural and geotechnical verification according to the limit state principle.”

*Delete the old paragraph (5):*

“(5) This document is also applicable for:

— structural assessment of existing structures;

— developing the design of repairs, improvements and alterations;

— assessing changes of use.

NOTE Additional or amended provisions can be necessary.”

*Replace the paragraph (6) with:*

“(6) This document is also applicable for structures where materials or actions outside the scope of EN 1991 (all parts) to EN 1999 (all parts) are involved.

NOTE In this case, additional or amended provisions can be necessary.”

# Modifications to 1.2, Assumptions

*Replace subclause 1.2 with:*

“(1) It is assumed that reasonable skill and care appropriate to the circumstances is exercised in the design of new structure and assessment of existing structures, based on the knowledge and good practice generally available at the time the structure is designed.

(2) It is assumed that the design and assessment of the structure is made by appropriately qualified and experienced personnel.

(3) The design rules provided in the Eurocodes assume that:

— execution will be carried out by personnel having appropriate skill and experience;

— adequate control and supervision will be provided during design, assessment and execution of the works, whether in factories, plants, or on site;

— construction materials and products for new structures or new structural members will be used in accordance with the Eurocodes, in the relevant product and execution standards, and project specifications;

— the structure will be adequately maintained;

— the structure will be used in accordance with the assumptions.

NOTE Guidance on management measures to satisfy the assumptions for design, assessment and verification and execution is given in Annex B.”

# Modifications to 3.1, Terms and definitions

*Add the following new term 3.1.1.4, then have the former term 3.1.1.4 and the following terms automatically renumbered:*

“3.1.1.4

existing structure

any structure that physically (materially) exists”

*Add the following new term 3.1.1.8, then have the former term 3.1.1.8 and the following terms automatically renumbered:*

“3.1.1.8

coastal structure

structure located in the coastal zone, opposing wave attacks or protecting against erosion, exposed to actions arising from environmental sea conditions, specifically waves, water-levels and currents and where those actions are likely to be the dominant action(s) affecting the load case of the structure

EXAMPLE Examples of coastal structures are:

— cylindrical structures, fixed decks, fluid conduits, e.g. slender structures such as single piles, pile arrays, inclined or horizontal structural members, sea outfalls;

— mound breakwaters, e.g. rubble mound breakwaters armoured with one or more layers of rock or concrete units;

— vertical faced breakwaters, e.g. caisson type breakwaters either surrounded by water or protecting land (reclaimed or not);

— composite breakwaters, e.g. combined rubble mound and vertical breakwaters;

— coastal embankments, e.g. sloping revetments protecting land, armoured with one or more layers of rock, concrete units or blocks;

— floating structures, such as pontoons, access platforms, moored barges.

Note 1 to entry: Port structures (piers, jetties, quaywalls, marine terminals, etc.) in sheltered marine areas are not considered as coastal structures. Port structures where wave or current actions are dominant actions are considered as coastal structures.”

*Replace the title of subclause 3.1.2 with:*

**“3.1.2 Terms relating to design and assessment”**

*Replace the term 3.1.2.2 with:*

“3.1.2.2

design situation

physical conditions expected to occur during a certain time period for which it is to be demonstrated, with sufficient reliability, that relevant limit states are not exceeded

Note 1 to entry: Design situations can also apply to situations for assessment of existing structures.”

*Replace the term 3.1.2.24 with:*

“3.1.2.24

structural reliability

ability of a structure or a structural member to fulfil the specified requirements during the service life for which it has been designed

Note 1 to entry: Reliability covers safety, serviceability and durability of a structure.

Note 2 to entry: For existing structures the ability to fulfil the requirements during the remaining service life will be relevant.”

*Add the following new terms 3.1.2.25 and 3.1.2.26, then have the former terms 3.1.2.25 and 3.1.2.26 and the following terms automatically renumbered:*

“3.1.2.25

assessment of an existing structure

verification of the reliability of an existing structure

3.1.2.26

structural performance

quantitative indicator of structural behaviour

EXAMPLE Indicators can be structural safety, serviceability, durability or robustness.”

*Add the following new term 3.1.2.28, then have the former term 3.1.2.28 and the following terms automatically renumbered:*

“3.1.2.28

risk

expected value of the magnitude of the consequences of failure, i.e. the sum of the products of the magnitude of possible consequences of a failure event and the corresponding probability”

*Add the following new term 3.1.4.1; then have the former term 3.1.4.1 and the following terms automatically renumbered:*

“3.1.4.1

material property

physical or chemical attribute of a construction material”

*Replace the term 3.1.4.4 with:*

“3.1.4.4

design value of a material or product property

*X*d

value obtained by dividing the representative value of a material or product property by a partial material factor

Note 1 to entry: In special circumstances, the value may be obtained by direct determination.

Note 2 to entry: For specific rules, see the other Eurocodes.”

*Add the following new subclauses 3.1.8 and 3.1.9:*

**“3.1.8 Terms relating to silos and tanks**

3.1.8.1

silo

single containment structure used to store particulate solids (also known as a bunker, bin or silo cell)

Note 1 to entry: This term also refers to a single cell in a silo battery.

3.1.8.2

silo battery

group of containment structures closely linked, permitting many different types of similar solids to be stored separately

Note 1 to entry: In some languages the term “silo” is also used to mean a silo battery.

3.1.8.3

process silo

silo that is regularly filled and partially or fully discharged throughout each year (more than 50 times per year)

3.1.8.4

storage silo

silo with an inflow and/or partial discharge less than 50 times per year

Note 1 to entry: See 4.2.

3.1.8.5

silo discharge load

the pressures acting on the walls of a silo during the discharge process, assuming that the silo is still in its full condition, but that the flow pattern of the discharge has been fully developed or during simultaneous filling and discharge

3.1.8.6

silo filling load

the pressures acting on the walls of a silo during the filling process and during storage in the full condition

3.1.8.7

tank

containment structure used to store liquids and/or gasses

3.1.8.8

tank load

the condition of a tank filled to the specified maximum level of liquid and with internal pressure from the liquid and pressure or suction from contained gas, vapour or air above the liquid surface

**3.1.9 Terms relating to structures supporting cranes or other machines**

3.1.9.1

machine

assembly, fitted with or intended to be fitted with a drive system consisting of linked parts or components, at least one of which moves, and which are joined together for a specific application

Note 1 to entry: The design of machines is outside the scope of the Eurocodes, since machines are covered by Machinery Directive.

3.1.9.2

crane

machine intended for the hoisting and moving in space of a load suspended by means of a hook or other load-handling device

Note 1 to entry: For crane design, see EN 13001.

Note 2 to entry: When the term “machine” is used, it refers to machines other than cranes.

3.1.9.3

structure supporting cranes or machines

civil engineering structure or structural part that is exposed to crane or machine induced actions

3.1.9.4

parts of the crane

all fixed and movable elements permanently assembled to form the crane itself

EXAMPLE The main crane structure, the hoist medium(s), and the fixed load lifting attachments.

Note 1 to entry: Elements not easily detachable from the crane are part of the crane.

3.1.9.5

hoist

load-lifting and/or load-lowering mechanism

[SOURCE: prEN 1991-3:2024, 3.1.2.1]

3.1.9.6

trolley

assembly designed to traverse the suspended load

[SOURCE: prEN 1991-3:2024, 3.1.2.2]

3.1.9.7

main structure of crane

major structural part of the crane, including if exist counterweight(s), trolley, if present, mechanical and electrical equipment

[SOURCE: prEN 1991-3:2024, 3.1.2.3]

3.1.9.8

hoist medium

wire rope(s), chain(s) or any other equipment hanging down from the crane used to lift and lower loads suspended from the lower end(s) of the hoist medium(s)

Note 1 to entry: Hoist mediums are part of the crane.

[SOURCE: prEN 1991-3:2024, 3.1.2.4]

3.1.9.9

fixed load-lifting attachment

any equipment, from which the net load can be suspended and which is permanently fastened to the lower end(s) of the hoist medium(s)

Note 1 to entry: Fixed load-lifting attachments are part of the crane.

[SOURCE: prEN 1991-3:2024, 3.1.2.5]

3.1.9.10

non-fixed load-lifting attachment

any equipment which connects the payload with the crane and which is neither part of the crane nor the payload

Note 1 to entry: Non-fixed load-lifting attachments are easily detachable from the crane and from the payload.

[SOURCE: prEN 1991-3:2024, 3.1.2.6]

3.1.9.11

payload

load which is lifted by the crane and suspended from the non-fixed load-lifting attachment(s) or, if such an attachment is not used, directly from the fixed load-lifting attachments

Note 1 to entry: If cranes are used for lifting gates at hydro-power stations or for lifting the load from water, the payload may also include forces due to waterflow suction or water adhering by suction.

[SOURCE: prEN 1991-3:2024, 3.1.2.7]

3.1.9.12

net load

load, which is lifted by the crane and suspended from the fixed load-lifting attachment(s)

Note 1 to entry: Net load contains the payload and the non-fixed load-lifting attachment(s).

[SOURCE: prEN 1991-3:2024, 3.1.2.8]

3.1.9.13

rated capacity

maximum net load that the crane is designed to lift for a given crane configuration and load location during normal operation

3.1.9.14

skewing

deviation from free-rolling, natural travelling or traversing direction.

[SOURCE: prEN 1991-3:2024, 3.1.2.10]

3.1.9.15

normal service conditions

all operations of a crane or machine that occur if the crane or machine is used for its intended purpose

3.1.9.16

working cycle

sequence of movements which commences when the crane is ready to hoist the payload, and ends when the crane is ready to hoist the next payload”

# Modifications to 3.2, Symbols and abbreviations

*Add the following new symbols in the relevant subclause to 3.2:*

“

|  |  |
| --- | --- |
| *A*ref,x | Appropriate reference area |
| *F*fat,eq | Fatigue damage equivalent action |
| *G*main | Self-weight of main structure of a crane |
| *G*sus | Self-weight of suspended parts of a crane |
| LDi | Limited displacement |
| SDi | Severe displacement |
| *γ*Q,L | Partial factor for variable liquid loads |
| *γ*Q,V | Partial factor for variable gas or vapour pressure |
| *φ*I | Importance factor |

”

*Replace the definitions of the following symbols:*

*“*

|  |  |
| --- | --- |
| *F*wk | Characteristic wind force |
| *G*exp | Shear modulus determined by testing |
| *Q*Lk | Characteristic horizontal force resulting from acceleration and braking |

*”*

*Rename the following symbols:*

*d*execution *is renamed* *d*exe

Φ *is renamed* Φ()

*Φ*dyn *is renamed Φ*

*Delete the symbol* *q*1k.

# Modifications to 6.1.2.1, General

*In the paragraph (1), delete Note 1, then unnumber the following note:*

“NOTE 1 Representative values are not defined for accidental and seismic actions, nor for bearing forces.”

# Modifications to 6.2, Material and product properties

*Replace the paragraph (4) with:*

*“*(4) Material properties should be determined from standard tests performed under specified conditions that provide reliable and accurate values at a sufficient confidence level.

NOTE 1 Reliable and accurate material and product properties are needed to achieve the level of structural reliability specified in the Eurocodes.

NOTE 2 Standard tests and conditions used to ensure reliable and accurate material and product properties are typically given in material and product standards referenced in the relevant Eurocode. Where no suitable standard exists, the Eurocodes can include provisions on determining material and product properties required for design.

NOTE 3 For the determination of material and product properties from test results, see also Annex D.”

*In the paragraph (6), add a new note in the end:*

“NOTE For geotechnical structures, best estimate values can also be used. See EN 1997 (all parts).”

*Replace the paragraph (7) with:*

“(7) When material or product properties are not specified in the Eurocodes, or when nominal values are selected, their values should be chosen and specified in the design to achieve a level of structural reliability no less than that in the Eurocodes.

NOTE For guidance on structural reliability, see Annex C.”

# Modifications to 8.3.3.8, Partial factors

*Delete the footnote:*

“The Clauses A.3, A.4, A.5 and A.6 will be published in subsequent amendments.”

# Modifications to A.1.2, Scope and field of application

*Replace the paragraphs (1), (2) and (3) with the following:*

“(1) This Clause A.1 applies to the verification by the partial factor method of buildings and associated geotechnical structures.

(2) This Clause A.1 applies to the verification by the partial factor method of geotechnical structures not covered by Clauses A.2 to A.6.

(3) This Clause A.1 may also be applied to the verification by the partial factor method of structures not covered by Clauses A.2 to A.6.

NOTE In this case, additional or amended provisions can be necessary.”

# Modifications to A.1.6.2, Serviceability limit states (SLS)

*In Table A.1.6 “Combinations of actions for serviceability limit states”, replace footnote a with the following:*

“a The characteristic value of prestressing *P*k can be an upper, lower, or a single characteristic value. Guidance is given in the other Eurocodes.”

*Replace Table A.1.7 (NDP) “Combination factors for buildings” with the following:*

“

| **Action** | ***ψ*0** | ***ψ*1** | ***ψ*2** |
| --- | --- | --- | --- |
| Imposed loads in buildings (see EN 1991-1-1):  Category A: areas for domestic and residential activities  Category B: public areas (not susceptible to crowding)  Category C: public areas where people can congregate  Category D: shopping areas  Category E: areas for archive, storage and industrial use | 0,7  0,7  0,7  0,7  1,0 | 0,5  0,5  0,7  0,7  0,9 | 0,3  0,3  0,6  0,6  0,8 |
| Category F and G: garages and vehicle traffic areas  — vehicle weight ≤ 30 kN  — 30 kN < vehicle weight ≤ 160 kN  — vehicle weight > 160 kN  Category H: roofs not accessible except for normal maintenance and repair  Category I: roofs accessible with occupancy  — roofs for categories A, B, G1 and G2  — roofs for categories C, D and F  — roof for category E  Category K: roofs accessible for special services  Category S: stairs and landings  — stairs and landings to areas belonging to category A1 and B1  — stairs and landings for tribunes without fixed seats that are defined as escape ways  — other stairs and landings  Category T: terraces and balconies | 0,7  0,7  0,7  0,5  0,5  0,5  1,0  0,5  0,7  0,7  0,7  0,7 | 0,7  0,5  0,5  0  0,3  0,5  0,9  0,3  0,5  0,7  0,5/0,3  0,7 | 0,6  0,3  0,3  0  0,2  0,4  0,8  0  0,3  0,6  0,3/0  0,7 |
| Construction actions (see EN 1991-1-6)b | 0,8 | 0,5 | 0,3 |
| Snow loads on buildings (see EN 1991-1-3):  — Finland, Iceland, Norway, Sweden; | 0,7 | 0,5 | 0,2 |
| — remainder of CEN Member States, for sites located at altitude H > 1 000 m a.s.l.; | 0,7 | 0,5 | 0,2 |
| — remainder of CEN Member States, for sites located at altitude H ≤ 1 000 m a.s.l. | 0,5 | 0,2 | 0 |
| Wind actions on buildings (see EN 1991-1-4) | 0,6 | 0,2 | 0 |
| Temperature (non-fire) in buildings (see EN 1991-1-5) | 0,6 | 0,5 | 0 |
| Icing (see EN 1991-1-9) | 0,5 | 0,2 | 0 |
| Water actionsa (see 6.1.3.2) | - | - | - |
| Waves and currents (see EN 1991-1-8) |  |  |  |
| a The combination value for water actions can be based on a 10 % probability that it is exceeded during a one-year reference period.  b In general, the relevant combinations of actions for serviceability limit states during execution are the characteristic combination and the quasi-permanent combination. | | | |

*”*

# Modifications to A.1.7, Partial factors for ultimate limit states (ULS)

*In the paragraph (1), replace NOTE 1 with:*

“NOTE 1 Values of the partial factors *γ*F and *γ*E for new, existing and rehabilitated structures are given in Table A.1.8 (NDP) for persistent and transient (fundamental) design situations, unless the National Annex gives different values.”

# Modifications to A.2.2, Scope and field of application

*Replace the paragraph (1) with the following:*

“(1) This Clause A.2 applies to road bridges, footbridges and railway bridges.

NOTE 1 This Clause A.2 provides the specific application of the general rules in Clauses 1 to 8 for these structures.

NOTE 2 Guidance on additional design measures to enhance structural robustness for bridges is given in Annex E.”

# Modifications to A.2.7.1, Ultimate limit states (ULS)

*In the paragraph (1), replace Note 6 with the following:*

“NOTE 6 The characteristic value of prestressing *P*k can be an upper, lower, or single characteristic value, as specified in the other Eurocodes.”

# Modifications to A.2.7.2, Serviceability limit states (SLS)

*In the paragraph (1), replace the Note with the following:*

“NOTE The characteristic value of prestressing *P*k can be an upper, lower, or a single characteristic value, as specified in the other Eurocodes.”

# Modifications to A.2.7.6.3, Combinations of wind and traffic

*Replace the paragraph (5) with the following:*

“(5) If a structural member is not directly exposed to wind, the action due to aerodynamic effects should be determined for train speeds enhanced by the speed of the wind.

NOTE This can apply when wind acts in the line of the train but in the opposite direction.”

# Modifications to A.2.8, Partial factors for ultimate limit states (ULS)

*In the paragraph (1), replace NOTE 1 with the following:*

“NOTE 1 Values of the partial factors *γ*F for new, existing and rehabilitated structures are given in Table A.2.10 (NDP) for persistent and transient design situations, unless the National Annex gives different values.”

# Modifications to A.2.9.4.2.2, Deck twist

*In the paragraph (2), replace the symbol Φ*dyn *with the symbol Φ.*

# Modifications to A.2.9.4.2.3, Vertical deformation of the deck

*In the paragraph (1), replace the symbol Φ*dyn *with the symbol Φ.*

# Modifications to A.2.9.4.2.4, Transverse deformation and vibration of the deck

*In the paragraph (1), replace the symbol Φ*dyn *with the symbol Φ.*

# Modifications to A.2.9.4.3.2, Vertical deflection

*In the paragraph (1), replace the symbol Φ*dyn *with the symbol Φ.*

# Addition of new Clauses A.3, A.4, A.5 and A.6 in Annex A, Application rules

*Add the following new Clauses A.3, A.4, A.5 and A.6:*

“

* 1. Application for towers, masts and chimneys
     1. Scope and field of application

(1) This Clause A.3 applies to the verification by the partial factor method of towers, masts and chimneys.

NOTE 1 This Clause A.3 provides the specific application of the general rules in Clauses 1 to 8 for these structures.

NOTE 2 Towers, masts and chimneys are typically made of concrete, steel, timber, masonry, aluminium and glass reinforced polymers.

NOTE 3 Structural requirements for overhead electrical lines are covered by EN 50341 (all parts), for wind turbines by EN IEC 61400 (all parts) and for lighting columns by EN 40 (all parts).

(2) When a structure falls into the field of application of different parts of Annex A, these parts should be applied in conjunction, as specified by the relevant authority or, where not specified, agreed for a specific project by the relevant parties.

* + 1. Consequence classes

(1) Towers, masts and chimneys should be classified into consequence classes, according to the consequences of their failure as described in 4.3.

NOTE Examples of towers, masts and chimneys in different consequence classes are given in Table A.3.1 (NDP), unless the National Annex gives different examples.

Table A.3.1 (NDP) — Examples of towers, masts and chimneys in different consequence classes

|  |  |  |
| --- | --- | --- |
| **Consequence class**a | **Description of consequences** | **Examples** |
| CC3 | High | Towers, masts and chimneys, which in case of failure have higher possibility to cause injuries or loss of human lives, higher economic or environmental consequences, built in strategic locations, or represent monumental construction work, e.g. high structures in urban areas, towers and masts serving crucial telecommunication facilities, chimneys serving critical plants. |
| CC2 | Normal | Towers, masts and chimneys, which do not belong to consequence classes CC3 or CC1, e.g. structures built in urban areas or in large plants. |
| CC1 | Low | Towers, masts and chimneys which in case of failure have a lower possibility to cause injuries or loss of human lives, lower economic or environmental consequences, e.g. towers and masts built in sparsely populated areas, small chimneys in industrial areas. |
| CC0 | Lowest | Where a level of reliability lower than for CC1 can be considered with respect to a possibility to cause social, economic or environmental consequences, e.g. towers and masts built in uninhabited areas. |
| a For provisions concerning CC0 and CC4, see 4.3. | | |

* + 1. Design service life

(1) The design service life *T*lf of a tower, mast or chimney, as described in 4.5, should be specified.

NOTE The value of *T*lf is given in Table A.3.2(NDP) for different categories of towers, masts and chimneys, unless the National Annex gives different values or categories.

(2) The design service life should be used to determine the time-dependent performance of the structure.

Table A.3.2 (NDP) — Design service life categories for towers, masts and chimneys

|  |  |
| --- | --- |
| **Category of towers, masts and chimneys** | **Design service life *T*lf** years |
| Significant or monumental structures | 100 |
| Common structures | 30 – 50 |
| Temporary structuresa | ≤ 10 |
| a For structures or parts of structures that can be dismantled in order to be reused, see 4.5(3). | |

* + 1. Actions

(1) The actions, as described in Clause 6, to be included in the design of structures shall be those defined by EN 1991 (all parts), EN 1997 (all parts), and EN 1998 (all parts).

* + 1. Combinations of actions
       1. Ultimate limit states (ULS)

(1) Combination of actions for ultimate limit states with partial factors on actions should be chosen depending on the design situation.

NOTE 1 The formula to be used is Formula (8.12), unless the National Annex gives a different choice, see 8.3.4.2(2).

NOTE 2 When using Formula (8.12), the combinations of actions for persistent and transient design situations are according to Table A.3.3 (NDP), unless the National Annex gives a different choice, see 8.3.4.2(2).

NOTE 3 When using combinations of actions based on Formula (8.13) or Formula (8.14) the value of *ξ* is 0,85, unless the National Annex gives a different value.

NOTE 4 As defined in 8.3.2.1, partial factors on actions are used, and Formula (8.4) applies, for the design of:

— linear and non-linear structural systems;

— certain types of geotechnical structure, in accordance with the relevant part of EN 1997.

NOTE 5 The characteristic value of prestressing Pk can be an upper, a lower, or a single characteristic value, as specified in the other Eurocodes.

NOTE 6 In accidental design situations, the choice between *ψ*1 and *ψ*2 depends on details of the design situation, e.g. impact, fire, or survival after an accidental event or situation. Further guidance is given in the other Eurocodes and in the National Annex.

(2) When using the lower parts of Formula (8.13) and Formula (8.14), the value of *ξγ*G shall not be less than 1,0.

Table A.3.3 (NDP) — Combinations of actions for ultimate limit states

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Design situation** | **Persistent and transient (fundamental)** | **Accidental** | **Seismic**a | **Fatigue**b |
| General formula for effects of actions | (8.4) | | | |
| Formula for combination of actions | (8.12) | (8.15) | (8.16) | (8.17) |
| Permanent (*G*d,i) | *γ*G,*i*𝐺k,*i* | 𝐺k,*i* | 𝐺𝑘,*i* | 𝐺k,*i* |
| Leading variable (*Q*d,1)d | *γ*Q,1𝑄k,1 | 𝜓1,1𝑄k,1 or 𝜓2,1𝑄k,1 | 𝜓2,*j*𝑄k,*j* | c |
| Accompanying variable (*Q*d,j)d | *γ*Q,*j*𝜓0,*j*𝑄k,*j* | 𝜓2,*j*𝑄𝑘,*j* |
| Prestressing (*P*d) | *γ*P𝑃k | 𝑃k | 𝑃k | 𝑃k |
| Accidental (*A*d) | - | 𝐴d | - | - |
| Seismic (*A*Ed) | - | - | 𝐴Ed,ULS | - |
| Fatigue (*F*fat) | - | - | - | *γ*Ff Ffat |
| a Depending on the magnitude of *A*Ed,ULS, the seismic combination of actions covers both the near collapse (NC) and significant damage (SD) ultimate limit states defined in EN 1998 (all parts).  b For conditions of use, see 8.3.4.5.  c The action type of which *F*fat is considered should not be taken into account as variable in the combination.  d For the reduction of wind pressure in combination with icing, see EN 1991-1-9. | | | | |

(2) Combination of actions for ultimate limit states with factors on effects of actions should be chosen according to 8.3.2.3.

NOTE As defined in 8.3.2.1, partial factors on effects of actions are used, and Formula (8.5) applies for the design of:

— certain types of geotechnical structure, in accordance with the relevant part of EN 1997;

— ropes, cables and membrane structures, where the application of partial factors on the effects of actions is more adverse than the application of partial factors on actions.

(3) For design of cooling towers and chimneys, the stepped temperature component (see prEN 1991-1-5:2023, 9.4) should be considered to act simultaneously with wind.

* + - 1. Serviceability limit states (SLS)

(1) Combinations of actions for serviceability limit states, for which 8.4.3 and the general Formula (8.28) apply, should be chosen according to Table A.3.4, depending on the combinations of actions being considered.

Table A.3.4 — Combinations of actions for serviceability limit states

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Combinations** | **Characteristic** | **Frequent** | **Quasi-permanent** | **Seismic**b |
| General formula for effects of actions | (8.28) | | | |
| Formula for combination of actions | (8.29) | (8.30) | (8.31) | (8.32) |
| Permanent (*G*d,*i*) | 𝐺k,*i* | 𝐺k,*i* | 𝐺k,*i* | 𝐺k,*i* |
| Leading variable (*Q*d,1)c | 𝑄k,1 | 𝜓1,1𝑄k,1 | 𝜓2,*j* 𝑄k,*j* | 𝜓2,*j* 𝑄k,*j* |
| Accompanying variable (*Q*d,*j*)c | 𝜓0,*j* 𝑄k,*j* | 𝜓2,*j* 𝑄k,*j* |
| Prestressing (*P*d)a | *P*k | *P*k | *P*k | *P*k |
| Seismic (*A*Ed) | - | - | - | 𝐴Ed,SLS |
| a The characteristic value of prestressing *P*k can be an upper, lower, or a single characteristic value. Guidance is given in the other Eurocodes.  b Depending on the magnitude of *A*Ed,SLS, the seismic combination of actions covers both the damage limitation (DL) and fully operational (OP) serviceability limit states defined in EN 1998 (all parts).  c For the reduction of wind pressure in combination with icing, see EN 1991-1-9. | | | | |

* + - 1. Combination factors

(1) Combinations of actions may be calculated using the combination factors *ψ*, as defined in 6.1.2.3(3).

NOTE Values of the combination factors *ψ* are given in Table A.3.5 (NDP), unless the National Annex gives different values.

Table A.3.5 (NDP) — Combination factors for towers, masts and chimneys

|  |  |  |  |
| --- | --- | --- | --- |
| **Action** | ***ψ*0** | ***ψ*1** | ***ψ*2** |
| Imposed loads (see EN 1991-1-1) | a | a | a |
| Construction actions (see EN 1991-1-6) | 1,0 | – | 0,2 |
| Wind loads (see EN 1991-1-4) | 0,6 | 0,2 | 0 |
| Icing (see EN 1991-1-9) | 0,5 | 0,2 | 0 |
| Temperature (non-fire) (see EN 1991-1-5) | 0,6 | 0,5 | 0 |
| a Depends on the category of imposed load. | | | |

* + 1. Partial factors for ultimate limit states (ULS)

(1) Ultimate limit states may be verified using partial factors *γ*F applied to actions or *γ*E applied to effects of actions, as defined in 8.3.

NOTE 1 Values of the partial factors for actions *γ*F and effects of actions *γ*E are given in Table A.3.6 (NDP) for persistent and transient (fundamental) design situations, unless the National Annex gives different values.

NOTE 2 Values of consequence factor *k*F for different consequence classes in Table A.3.1 (NDP) are given in Table A.3.7 (NDP), unless the National Annex gives different values.

NOTE 3 For ultimate limit states verification of fatigue and vibrations, see 8.3.3.6.

(2) The value of the partial factors *γ*F when applied to unfavourable actions or actions effects shall not be less than 1,0.

(3) The value of the partial factor *γ*P on initial prestress of guys should be taken as 1,0.

(4) Ultimate limit states for persistent and transient design situations that involve structural resistance should be verified using partial factors for verification case VC1.

(5) When variations in the magnitude or spatial variation of permanent actions from a single source (see 6.1.1(4)) are significant, ultimate limit states that involve loss of static equilibrium and/or strength elements contributing to the equilibrium, should be verified using partial factors for verification cases VC2(a) and VC2(b), using whichever gives the less favourable design outcome.

(6) Verification of verification case VC2(b) may be omitted when it is obvious that verification using VC2(a) governs the design outcome.

(7) Ultimate limit states that involve failure of ground should be verified using partial factors for verification cases VC1, VC2, VC 3 and VC4, in accordance with the relevant part of EN 1997.

NOTE The relevant part of EN 1997 gives guidance on which verification cases to use for different geotechnical structures.

Table A.3.6 (NDP) — Partial factors on actions and effects for verification case VC1 to VC4 for persistent and transient (fundamental) design situations

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Action or effect** | | | **Partial factors *γ*F and *γ*E for verification cases** | | | | |
| **Type** | **Symbol** | **Resulting effect** | **Structural resistance** | **Static equilibrium and uplift** | | **Geotechnical design** | |
| **Verification case** | | | **VC1**a | **VC2(a)**b | **VC2(b)**b | **VC3**c | **VC4**d |
| Permanent action (*G*k) | *γ*G | unfavourable/ destabilising | 1,35 *k*F | 1,35*k*F | 1,0 | 1,0 | *G*k is not factored |
| *γ*G,stb | stabilisingf | not used | 1,15e | 1,0 | not used |
| *γ*G,fav | favourableg | 1,0 | 1,0 | 1,0 | 1,0 |
| Prestressing (*P*k) | *γ*Pi |  | 1,0 | 1,0 | 1,0 | 1,0 |  |
| Variable action (*Q*k) | *γ*Q | unfavourable | 1,5 *k*F | 1,5*k*F | 1,5*k*F | 1,3 | *γ*Qredh |
| *γ*Q,fav | favourable | 0 | | | | |
| Effects of actions (*E*) | *γ*E | unfavourable | *γ*E is not applied | | | | 1,35 *k*F |
| *γ*E,fav | favourable | 1,0 |
| a Verification case VC1 is used both for structural and geotechnical design. Formula (8.4) is used for VC1.  b Verification case VC2 is used for the combined verification of strength and static equilibrium, when the structure is sensitive to variations in permanent actions arising from a single source. Values of *γ*F are taken from VC2(a) or VC2(b), whichever gives the less favourable outcome. See 8.3.3.1(5). Formula (8.4) is used for VC2.  c Verification case VC3 is typically used for the design of slopes and embankments, spread foundations and gravity retaining structures. See EN 1997 (all parts) for details. Formula (8.4) is used for VC3.  d Verification case VC4 is typically used for the design of transversally loaded piles and embedded retaining walls and (in some countries) gravity retaining structures. See EN 1997 for details. Formula (8.5) is used for VC4.  e The value of *γ*G,stb= 1,15 is based on *γ*G,inf = 1,35*ρ* with *ρ*= 0,85.  f Applied to the stabilizing part of an action originating from a single source.  g Applied to actions whose entire effect is favourable and independent of the unfavourable action.  h *γ*Q,red = *γ*Q1/*γ*G1 where *γ*Q = corresponding value from VC1 and *γ*G1 = corresponding value of *γ*G from VC1.  i For the definition of *γ*P where *γ*P is materially independent, see other relevant Eurocodes. | | | | | | | |

Table A.3.7 (NDP) — Consequence factors for towers, masts and chimneys

|  |  |  |
| --- | --- | --- |
| **Consequence class CC** | **Description of consequences** | **Consequence factor  *k*F** |
| CC3 | High | 1,1 |
| CC2 | Normal | 1,0 |
| CC1 | Low | 0,9 |
| CC0 | Lowest | 0,8 |

* + 1. Serviceability criteria
       1. General

(1) Serviceability limit states should be specified for each design project for towers, masts and chimneys in accordance with 5.4.

(2) Serviceability criteria can include for example:

— deflections or rotations that adversely affect the effective use or appearance of the structure;

— limitation of cracking of concrete;

— vibrations, oscillations or sway that may cause alarm among bystanders or causes e.g. loss of transmitted signals;

— deformations, deflections, differential settlements, vibrations, oscillations or sway that causes damage to non-structural elements.

NOTE Further information can be given in the other Eurocodes.

(3) The serviceability criteria should be as specified by the relevant authority or, where not specified, as agreed for the specific project by the relevant parties.

NOTE Further guidance can be given in the National Annex.

* + - 1. Deflections and rotations

(1) The maximum deflections and rotations should be calculated, when necessary, using the appropriate combinations of actions, as specified in Table A.3.4, accounting for the serviceability requirements given in 5.4(1).

NOTE Guidance on the calculation of deformations is given in other Eurocodes.

(2) The deflections and rotations for towers, masts and chimneys should be calculated making due allowance for any second order or dynamic effects.

(3) The deformations obtained using a combination of actions do not include the effects of execution tolerances and these should be considered additionally, if significant.

(4) Limiting values should be specified together with the load case considered.

NOTE Guidance for specification of limiting values of deflections and rotations in steel towers, masts and chimneys is given in EN 1993-3.

* + - 1. Vibrations

(1) Towers, masts and chimneys should be examined for:

— gust induced vibrations (causing vibrations predominantly in the direction of the wind);

— vortex induced vibrations (causing vibrations perpendicular to the direction of the wind);

— ovalling;

— galloping instability;

— other aspects agreed with the relevant authority or agreed for a specific project by the relevant parties.

NOTE 1 For dynamic effects due to wind, see EN 1991-1-4.

NOTE 2 Vibrations can cause development of fatigue damage.

NOTE 2 For further guidance on fatigue damage of steel towers, masts and chimneys, see EN 1993-3.

(2) The maximum values for the cross-wind vibration amplitudes at the top of a self-supporting chimney, due to vortex shedding should be limited.

NOTE For guidance on the determination of maximum vibration amplitudes, see prEN 1991-1-4:202X, Annex E.

* + - 1. Limiting foundation movements

(1) The design value of the serviceability criteria *C*d,SLS for foundation movement beneath a tower, mast or chimney shall be selected during the design.

(2) The sensitivity of a structure to foundation movement should be classified according to structural sensitivity classes.

NOTE For structural sensitivity classes, see Clause A.1.

(3) Maximum permitted differential settlements of foundations for different structural sensitivity classes should be specified.

NOTE Maximum differential settlements of foundations can be given in the National Annex.

* 1. Application for silos and tanks
     1. Field of application

(1) This Clause A.4 should be used for the design of silos and tanks.

NOTE This Clause A.4 provides the specific application of the general rules in Clauses 1 to 8 for these structures.

* + 1. Consequence classes
       1. Classifications for silos

(1) Silos shall be classified into consequence classes, according to the consequences of their failure as described in 4.3.

NOTE Examples of silos in different consequence classes are given in Table A.4.1 (NDP), unless the National Annex gives different examples for use in a country.

(2) The consequence class for a silo in a battery shall be determined by the conditions of the individual silo.

Table A.4.1 (NDP) — Examples of silos in different consequence classes

| **Consequence class** | **Description of consequence** | **Examples** |
| --- | --- | --- |
| CC4 | Highest | Silos storing toxic products (e.g. nuclear waste) that could cause great loss of life if released into the environment or the atmosphere. |
| CC3 | High | Largea silos at harbours or in urban areas where people are likely to be nearby.  Largea silos in major industrial plants (e.g. power stations, cement works, steel plants) where people are working in or near the silo.  A single silo that is critical to the entire operation of a vital industrial plant. |
| CC2 | Normal | Silos for typical industrial plant.  Silos at railheads and port facilities.  Silos not classified elsewhere. |
| CC1 | Low | Silos for local district agricultural storage. |
| CC0 | Lowest | Smalla isolated silos on farms or in small industrial facilities. |
| a Definitions of small and large can be given in the National Annex | | |

* + - 1. Classifications for tanks

(1) Tanks shall be classified into consequence classes, according to the consequences of their failure as described in 4.3.

NOTE Examples of tanks in different consequence classes are given in Table A.4.2 (NDP), unless the National Annex gives different examples.

(2) The consequence class for a tank in a group of tanks shall be determined by the conditions of the individual tank.

Table A.4.2 (NDP) — Examples of tanks in different consequence classes

| **Consequence class** | **Description of consequence** | **Examples** |
| --- | --- | --- |
| CC4 | Highest | Tanks storing toxic products (e.g. nuclear waste) that could cause great loss of life if released into the environment or the atmosphere. |
| CC3b | High | All tanks storing refrigerated liquefied gases.  Largea and mediuma tanks storing toxic, explosive or inflammable liquids.  Groups of tanks storing liquids at ambient or elevated temperature in which failure of one tank can lead to the progressive failure of many others (especially under fire conditions). |
| CC3a | High | Largea and mediuma pedestal tanks storing liquids at ambient temperature located near places where people work or live.  Tanks storing liquids at ambient temperature near or at the top of tall buildings. |
| CC2 | Normal | Tanks not classified elsewhere.  a) Smalla tanks storing toxic, explosive or inflammable liquids.  b) All pedestal tanks not in CC3.  c) Largea and mediuma ground-supported tanks storing water-polluting liquids. |
| CC1 | Low | Smalla ground-supported tanks storing water-polluting liquids.  Largea and mediuma ground-supported tanks for clean water storage. |
| CC0 | Lowest | Smalla ground-supported tanks for clean water storage. |
| a Definitions of larger, medium, and small can be given in the National Annex. | | |

* + 1. Design service life
       1. Silos

(1) The design service life *T*lf of a silo, as described in 4.5, should be specified.

NOTE The value of *T*lf is given in Table A.4.3 (NDP) for different categories of silos, unless the National Annex gives different values or categories.

(2) Additional requirements for the design service life should be as specified by the relevant authority or, where not specified, as agreed for a specific project by the relevant parties.

(3) The design service life *T*lf should be used to determine the time-dependent performance of the structure.

Table A.4.3 (NDP) — Design service life categories for silos

| **Category of silos** | **Indicative design service life *T*lf** years |
| --- | --- |
| Facilities of national importance, e.g.:  — majora industrial plant;  — majora port facilities | 50 |
| Mediuma sized facilities, e.g. at an industrial plant, railheads, and typical port facilities | 40 |
| Smalla industrial plant, farm silos | 30 |
| a Definitions of medium, small and major can be given in the National Annex. | |

* + - 1. Tanks

(1) The design service life *T*lf of a tank, as described in 4.5, should be specified.

NOTE The value of *T*lf is given in Table A.4.4 (NDP) for different categories of tanks, unless the National Annex gives different values or categories.

(2) The design service life *T*lf should be used to determine the time-dependent performance of the structure.

Table A.4.4 (NDP) — Design service life categories for tanks

| **Category of tanks** | **Indicative design service life *T*lf** years |
| --- | --- |
| Facilities of national importance, e.g. tank farms for secure long term storage | 50 |
| Port storage facilities, e.g. tank farms for receipt | 40 |
| Industrial facilities, e.g. tanks for specific industrial plant, water supply tanks | 30 |

* + 1. Actions

(1) The actions, as described in Clause 6, to be included in the design of structures shall be those defined by EN 1991 (all parts), EN 1997 (all parts), and EN 1998 (all parts).

NOTE Some guidance is given in prEN1991-4:2022, Annex A (for silos) and Annex B (for tanks).

* + 1. Combinations of actions
       1. Ultimate limit states (ULS) for silos and tanks
          1. General

(1) Combination of actions for ultimate limit states with factors on actions should be chosen depending on the design situation, according to Table A.4.5, based on use of Formula (8.12).

NOTE National Annex can give a different choice for combinations of actions based on Formulae (8.13) or (8.14) together with recommendation on partial factors and other reliability elements.

Table A.4.5 — Combinations of actions for ultimate limit states for silos and tanks

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Design situation** | **Design situation** | | | |
| **Persistent and transient (fundamental)**a | **Accidental**b | **Seismic**c | **Fatigue**e |
| **General formula for effects of actions** | **(8.4)** | | | |
| **Formula for combination of actions** | **(8.12)** | **(8.15)** | **(8.16)** | **(8.17)** |
| Permanent (*G*d,*i*) | *γ*𝐺,*i* 𝐺k,*i* | 𝐺k,*i* | 𝐺k,*i* | 𝐺k,*i* |
| Leading variable (*Q*d,1) | *γ*Q,1𝑄k,1 | *ψ*1,1𝑄k,1 or *ψ*2,1𝑄k,1 | *ψ*2,*j* 𝑄k,*j* | *ψ*2,*j*𝑄k,*j* |
| Accompanying variable (*Q*d,*j*) | *γ*Q,*j ψ*0,*j* 𝑄𝑘,j | *ψ*2,1𝑄k,1 |
| Prestress (*P*d)d | *γ*P𝑃k | 𝑃k | 𝑃k | 𝑃k |
| Accidental (*A*d) | - | 𝐴𝑑 | - | - |
| Seismic (*A*Ed) | - | - | 𝐴Ed,ULS | - |
| Fatigue (*Q*fat) | - | - | - | *F*fat |
| a For persistent and transient design situations, when *γ*Q,*j* *ψ*0,*j* ≈ 1, the design value of the accompanying variable action can be approximated by its characteristic value.  b In accidental design situations, the choice between *ψ*1 and *ψ*2 depends on details of the design situation, e.g. impact, fire, or survival after an accidental event or situation. Further guidance is given in other Eurocodes and in the National Annex.  c Depending on the magnitude of *A*Ed,ULS, the seismic combination of actions covers both the near collapse (NC) and significant damage (SD) ultimate limit states which are defined in EN 1998.  d The characteristic value of prestress Pk can be an upper, lower, or a single characteristic value, as specified in other Eurocodes.  e See 8.3.4.5 for conditions of use. | | | | |

* + - 1. Combinations of actions for serviceability limit states (SLS) for silos and tanks

(1) Combinations of actions for serviceability limit states, for which 8.4.2 and the general Formula (8.28) apply, should be chosen according to Table A.4.6 depending on the combinations of actions being considered.

Table A.4.6 — Combinations of actions for serviceability limit states for silos and tanks

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Combinations** | **Characteristic** | **Frequent** | **Quasi-permanent** | **Seismic**b |
| **General formula** | **(8.28)** | | | |
| **Formula for combination of actions** | **(8.29)** | **(8.30)** | **(8.31)** | **(8.32)** |
| Permanent (*G*d,*j*) | 𝐺k,*i* | 𝐺k,*i* | 𝐺k,*i* | 𝐺k,*i* |
| Leading variable (*Q*d,1) | 𝑄k,1 | *ψ*1,1𝑄 k,1 | *ψ*2,*j* 𝑄k,*j* | *ψ*2,*j* 𝑄k,*j* |
| Accompanying variable (*Q*d,*j*) | *ψ*0,*j*𝑄k,1 | *ψ*2,*j*𝑄k,*j* |
| Prestress (*P*d)a | *P*k | *P*k | *P*k | *P*k |
| Seismic (*A*Ed) | - | - | - | 𝐴Ed,SLS |
| a The characteristic value of prestress *P*k can be an upper, lower, or a single characteristic value. Guidance is given in other Eurocodes.  b Depending on the magnitude of 𝐴Ed,SLS, the seismic combination of actions covers both the damage limitation (DL) and fully operational (OP) serviceability limit states defined in EN 1998. | | | | |

* + - 1. Combination factors

(1) Combinations of actions should be determined using the combination factors *ψ*, as defined in 6.1.2.3(3).

NOTE Values of the combination factors *ψ* are given in Table A.4.7(NDP), unless the National Annex gives different values.

(2) Values of the combination factors *ψ*1 and *ψ*2 for tank and silo filling, discharge and test loads should be specified.

NOTE 1 For tank and silo filling, discharge and test loads, the *ψ*1 and *ψ*2 values are not given by nature, but depend on the use of the facility.

NOTE 2 In the absence of project-specific values, suggested values of the combination factors *ψ*1 and *ψ*2 for silo filling and discharge loads are given in Table A.4.8 (NDP), unless the National Annex gives different values.

(3) Values of the combination factors *ψ*1 and *ψ*2 for tank and silo filling, discharge and test loads should be as specified by the relevant authority or, where not specified, may be agreed for a specific project by the relevant parties.

Table A.4.7 (NDP) — Values of combination factors *ψ* for silos and tanks

| **Action** | ***ψ*0** | ***ψ*1** | ***ψ*2** |
| --- | --- | --- | --- |
| Silo filling load | 1,0 | -a | -a |
| Silo discharge load, storage silo | 1,0 | -a | -a |
| Silo discharge load, process silo | 1,0 | -a | -a |
| Tank load  — liquid  — gas or vapour  — process temperature | 1,0  1,0  1,0 | -a  -a  -a | -a  -a  -a |
| Tank test load  — hydrostatic  — pneumatic | 1,0  1,0 | -a  -a | -a  -a |
| Wind load | 0,6 | 0,2 | 0 |
| Snow load (see Table A.1.7) |  |  |  |
| Foundation settlement | 1,0 | 1,0 | 1,0 |
| Imposed loads or deformation | 0,7 | 0,5 | 0,3 |
| Thermal climatic actions (fire excluded) | 0,6 | 0,5 | 0 |
| Construction actions (see Table A.1.7) |  |  |  |
| a *ψ*1 and *ψ*2 values are not given. The frequency of these loads is not given by nature, but depends on the use of the facility. See A.4.5.3(2) and A.4.5.3(3). | | | |

Table A.4.8 (NDP) — Suggested values of combination factors *ψ*1 and *ψ*2 for silo filling and discharge loads

| **Action** | ***ψ*1** | ***ψ*2** |
| --- | --- | --- |
| Silo filling load | 0,9 | 0,8 |
| Silo discharge load, storage silo | 0,9 | 0,8 |
| Silo discharge load, process silo | 0,8 | 0,7 |

* + 1. Partial factors for ultimate limit states

(1) Ultimate limit states should be verified using partial factors *γ*F applied to actions as defined in 8.3.

(2) Ultimate limit states for persistent and transient design situations that involve structural resistance of the roof or top structure or the supporting sub-structure of a silo or tank should be verified using partial factors for VC1 in Table A.1.8 (NDP ).

(3) Ultimate limit states that involve the structural resistance of the silo structure should be verified using partial factors for verification case VC5.

NOTE 1 Values of the partial factors *γ*F for VC5 are given in Table A.4.9 (NDP) for persistent and transient design situations, unless the National Annex gives different values.

NOTE 2 Partial factors given in Table A.4.9 (NDP) and Table A.4.11 (NDP) are based on past practice and not necessarily lead to the target reliability indexes given in Annex C.

NOTE 3 Values of consequence factors kF are given in Table A.4.10 (NDP), unless the National Annex gives different values.

(4) Ultimate limit states that involve structural resistance of the tank structure should be verified using partial factors for verification case VC6.

NOTE Values of the partial factors γF and for consequence factors *k*F for VC6 are given in Table A.4.11 (NDP) and Table A.4.12 (NPD) for persistent and transient design situations, unless the National Annex gives different values.

(5) Ultimate limit states that involve loss of static equilibrium and/or strength of elements contributing to the equilibrium, should be verified using partial factors for VC2(a) and VC2(b) in Table A.1.8 (NDP), using whichever gives the less favourable design outcome.

(6) Verification of VC2(b) may be omitted when it is obvious that verification using VC2(a) governs the design outcome.

(7) Ultimate limit states that involve resistance of the foundation of a silo or tank for persistent and transient design situations should be verified using partial factors for VC1, VC3, or VC4 in Table A.1.8 (NDP) and as further specified in the relevant part of EN 1997.

Table A.4.9 (NDP) — Partial factors on actions for persistent and transient (fundamental) design situations for silo structures

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Action** | | | | **Partial factor *γ*F** |
| **Type** | **Group** | **Symbol** | **Resulting effect** | **Silo structure** |
| **Verification case** | | | | **VC5**a |
| Permanent action | All | *γ*G | Unfavourable /destabilizing | 1,35*k*F |
| All | *γ*G,fav | Favourable | 1,0 |
| Variable action | All, except those noted below | *γ*Q | Unfavourable | 1,5*k*F |
| Air pressure | *γ*Q | 1,2*k*F |
| Thermal action | *γ*Q | 1,0 |
| Silo load | *γ*Q | 1,35*k*F |
| Silo load | *γ*Q,fav | Favourable | 0 or 1,0b |
| a Formula (8.4) is used for VC5.  b *γ*F can be applied separately to unfavourable and favourable components of (single source) silo loads, e.g. for buckling verifications where load effects (horizontal forces) contributing favourably are factored 1,0 and load effects (vertical forces) contributing unfavourably are factored as unfavourable. | | | | |

Table A.4.10 (NDP) — Consequence factors for silos

|  |  |  |
| --- | --- | --- |
| **Consequence class CC** | **Description of consequences** | **Consequence factor *k*F** |
| CC3 | High | 1,1 |
| CC2 | Normal | 1,0 |
| CC1a | Low | 0,9 |
| a The value of the consequence factor for CC0 can be set equal to the value for CC1. | | |

Table A.4.11 (NDP) — Partial factors on actions for persistent and transient (fundamental) design situations for tank structures

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Action** | | | | **Partial factor *γ*F** |
| **Type** | **Group** | **Symbol** | **Resulting effect** | **Tank structure** |
| **Verification case** | | | | **VC6**a |
| Permanent action | All except self-weight of the tank wall | *γ*G | Unfavourable /destabilizing | 1,35*k*F |
| Tank shell wall | *γ*G | 1,35*k*Fb |
| All | *γ*G,fav | Favourable | 1,0 |
| Variable action | All, except those below | *γ*Q | Unfavourable | 1,5*k*F |
| Liquid load | *γ*Q,L | 1,15*k*F |
| Gas or vapour pressure bounded by process control | *γ*Q,V | 1,15*k*F |
| Gas or vapour pressure not bounded by process control | *γ*Q,V | 1,5*k*F |
| Thermal actions bounded by process control | *γ*Q | 1,15 *k*F |
| Climatic thermal actions | *γ*Q | 1,5 *k*F |
| Test loads (hydrostatic and/or pneumatic) | *γ*Q | 1,05 |
| a Formula (8.4) is used for VC6.  b When the uncertainties related to permanent actions for a tank shell wall is low, typically for a steel tank, a lower value of the partial factor, 1,2*k*F, is recommended. | | | | |

Table A.4.12 (NDP) — Consequence factors for tanks

|  |  |  |  |
| --- | --- | --- | --- |
| **Consequence class CC** | **Description of consequences** | **Consequence factor *k*F** | |
| CC3 | High | 1,05 | |
| CC2 | Normal | 1,00 | |
| CC1a | Low | 0,95 | |
| a The value of the consequence factor for CC0 can be set equal to the value for CC1. | | |

* 1. Application for structures supporting cranes or other machines
     1. Use of this annex

(1) This Clause A.5 contains additional provisions to the general rules in Clauses 1 to 9 for the structures specified in A.5.2.

* + 1. Scope and field of application

(1) This Clause A.5 applies to the verification by the partial factor method for the design of structures supporting cranes or other machines.

NOTE 1 For non-linear behaviour, see A.5.5.

NOTE 2 Symbols, notations, Load Models and groups of loads are supplemented by those used or defined in the relevant clauses of EN 1991-3, when relevant. See also symbols, notations and models of construction actions in EN 1991-1-6.

(2) This Clause A.5 may also be applied to structures supporting machines with rotating parts which induce dynamic effects in one or more planes.

NOTE Additional information can be needed.

(3) When a structure falls into the field of application of other parts of Annex A, these parts should be applied in conjunction.

* + 1. Consequence classes

(1) Structures supporting cranes or other machines should be classified into consequence classes according to the consequence of their failure as described in 4.3.

(2) Where a structure supporting cranes or other machines is part of a wider structure, the classification into consequence class of a structure supporting cranes or other machines should accord with the consequence class of the wider structure.

Note 1 Examples of construction works in different consequence classes are given in tables in relevant Annex A Clause, unless the National Annex gives different examples.

Note 2 In some case, consequence class of the construction works can increase due to the presence of the crane or the machine.

* + 1. Design service life

(1) The design service life *T*lf of a structure supporting cranes or other machines, as described in 4.5, should be specified.

NOTE The minimum value of *T*lf is 25 years, unless the National Annex gives different values.

(2) The design service life of the structure supporting cranes or other machines which is part of a wider structure should accord with the design service life of the wider structure.

(3) If the structure supporting cranes or other machines or part of it is designed to be replaceable, a reduced design service life may be assumed according to 4.5(4).

* + 1. Classification of actions from cranes and other machines
       1. General

(1) For the verification of the structures supporting cranes and other machines, the actions should be classified as permanent, variable and accidental actions, depending on their nature.

(2) Dynamic effects should be taken into account by means of suitable dynamic analysis, where relevant.

NOTE 1 When structure-action interaction can be disregarded, dynamic effects induced by vibrations due to inertial and damping forces in cranes and other machines can be accounted by dynamic factors *ϕ*i to be applied to the static action values, see for example EN 1991-3.

NOTE 2 For minor machines with only rotating parts, like washing machines and small ventilators, separate considerations of dynamic effects can be omitted, and their dynamic effects are generally included in the induced notional quasi static actions. A minor machine is weighing less than 5 kN and having a power less than 50 kW.

* + - 1. Permanent actions

(1) The self-weight of all fixed and moveable parts of the crane and static actions from service should be classified as permanent actions.

EXAMPLE Examples of permanent actions from crane and other machines include:

— self-weight of the suspended parts of the cranes, *G*sus, and of the main structure of the crane (*G*main);

— self-weight of the machine;

— actions from self-weight of pipe, forces and moments due to thermal expansion of pipes operating at practically constant temperature different from room temperature,

— actions from fluids; flows and flow pressure;

— effects of settlements.

(2) Self-weight of the crane structure should be considered as fixed or free action, depending on the crane typology.

NOTE Self-weights of different parts of the same crane can have different classification, for example:

— in a tower crane, the self-weight of the rotating arm or jib and the counterweight are free actions, the self-weight of the tower is a fixed action;

— in movable portal cranes, or cranes on runway beams, self-weights of all elements are free actions.

(3) When the simplified approach given in EN 1991-3 for crane travelling on fixed runway beams is adopted, effects of self-weight may be treated as variable actions.

* + - 1. Variable actions

(1) The variable crane actions should be separated into:

— vertical crane actions, e.g. caused by the net loads and vertical dynamic effects;

— horizontal crane actions, e.g. caused by acceleration or deceleration of crane, of the trolley and by the payload or by skewing or other horizontal dynamic effects.

(2) Simultaneity of the crane or machine load actions s should be taken into account.

(3) Variable actions from machines during normal service conditions should be considered, including dynamic effects.

NOTE Variable actions from machines include dynamic effects caused by accelerated masses such as:

— periodic frequency-dependent bearing forces due to eccentricities of rotating masses; mainly perpendicular to the axis of the rotors;

— depending on the type of machine, periodic actions due to service transmitted to the foundation;

— forces or moments due to switching on or off or other transient procedures such as synchronisations.

(4) The dynamic effects of actions induced by machines should be determined taking into account the interaction between the excitation from the machine and the structure, if relevant.

(5) Climatic actions on structures supporting cranes and other machines should be evaluated distinguishing the following cases:

a) structures supporting cranes or other machines, which are unshielded by the construction work;

b) structures supporting cranes or machines which are shielded by the construction work.

EXAMPLE Examples of unshielded structures supporting cranes or other machines are structures outside buildings; examples of shielded structures supporting cranes or other machines are structures inside buildings.

(6) For unshielded structures supporting cranes or other machines and, when relevant, for shielded structures supporting cranes or other machines the wind actions during service should be determined considering the maximum wind speed compatible with service, acting on the appropriate reference area *A*ref,x, according to EN 1991-1-4 and EN 1991-3.

NOTE 1 Indicative value of the maximum basic wind speed compatible with crane operations is 12 m/s, unless the National Annex gives a different value.

NOTE 2 The appropriate reference area *A*ref,x depends on the specific project.

NOTE 3 The maximum basic wind speed compatible with machine operations depends on the specific project.

(7) For unshielded structures supporting cranes or other machines and, when relevant, for shielded structures supporting cranes or other machines the wind actions in non-operational conditions should be determined according to EN 1991-1-4.

NOTE For wind actions during execution, See EN 1991-1-6.

* + - 1. Accidental actions generated by cranes or other machines

(1) When appropriate protections are not provided, accidental actions should be considered.

NOTE Accidental actions generated by cranes for cranes on fixed runway and by machines are given in EN 1991-3.

(2) When relevant, design values for accidental actions may be represented in the form of equivalent static loads.

(3) Where an accidental action needs to be taken into account, no other accidental action or wind action should be taken into account in the same combination, unless otherwise specified in other Eurocodes.

* + - 1. Groups of loads

(1) The simultaneity of crane load actions may be taken into account by considering suitable groups of loads.

NOTE 1 For combination with non-crane loads, the crane load components belonging to each group of loads can be considered as defining a single characteristic crane action.

NOTE 2 In service wind is a non-crane action.

* + 1. Combinations of actions
       1. General

(1) The relevant actions induced by cranes and other machines shall be determined for each design situation identified in accordance with section 5.2.

NOTE 1 Rules for multiple crane actions from cranes travelling on fixed runways are given in EN 1991-3.

NOTE 2 Design situations for machines are also aiming to assess that:

— the service conditions of the machine conform to the service requirements and no damage is induced to the structure supporting the machine and its foundation by accidental actions that would infringe the subsequent use of this structure for further service;

— the impact on the surroundings, for instance checking that disturbance of sensitive equipment is within acceptable limits.

* + - 1. Ultimate limit states

(1) Combination of actions for ultimate limit states with partial factors on actions should be chosen depending on the design situation, according to Table A.5.1, using Formula (8.12) for persistent/transient design situations.

Table A.5.1 — Combinations of actions for ultimate limit states (Formula (8.12))

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Design situation** | **Persistent and transient (fundamental)** | **Accidental**a | **Seismic**b | **Fatigue**d |
| **General formula for  effects of actions** | **(8.4)** |  |  |  |
| **Formula for combination of**  **actions** | **(8.12)** | **(8.15)** | **(8.16)** | **(8.17)** |
| Permanent actions (*G*d,*i*) | *γ*G,*i*𝐺k,*i* | 𝐺k,*i* | 𝐺k,*i* | 𝐺k,*i* |
| Leading variable action (*Q*d,1) | *γ*Q,1𝑄k,1 | *ψ*1,1𝑄k,1 or *ψ*2,1𝑄k,1 | *ψ*2,*j* 𝑄k,*j* | - |
| Accompanying variable action (*Q*d,*j*) | *γ*Q,*j* *ψ*0,*j*𝑄k,*j* | *ψ*2,*j* 𝑄k,*j* | *ψ*2,*j* 𝑄k,*j* |
| Prestressing (*P*d)c | *γ*P𝑃k | 𝑃k | 𝑃k | 𝑃k |
| Accidental (*A*d) | - | 𝐴d | - | - |
| Seismic (*A*Ed) | - | - | 𝐴Ed,ULS | - |
| Fatigue (*F*fat) | - | - | - | 𝛾Ff𝐹fate |
| a In accidental design situations, the choice between *ψ*1 and *ψ*2 depends on details of the design situation, e.g. accidental crane action, or impact, or fire, or survival after an accidental event or situation. Further guidance can be given in the other Eurocodes and in the National Annex.  b Depending on the magnitude of 𝐴Ed,ULS, the seismic combination of actions covers both the near collapse (NC) and significant damage (SD) ultimate limit states defined in EN 1998 (all parts).  c The characteristic value of prestressing *P*k can be an upper, lower, or a single characteristic value, as specified in the other Eurocodes.  d See 8.3.4.5 and A.5.8(7) for conditions of use.  e Actions inducing fatigue are all amplified by *γ*Ff. | | | | | |

(2) Combinations involving actions which are outside the scope of EN 1991 (all parts), e.g. due to mining subsidence or particular wind effects, should be defined in accordance with this document.

NOTE Minimum requirements for combinations involving actions that are outside the scope of EN 1991 (all parts) can be defined in the National Annex.

(3) Additional requirements for combinations involving actions that are outside the scope of EN 1991 (all parts) should be as specified by the relevant authority or, where not specified, as agreed for a specific project by the relevant parties.

* + - 1. Serviceability limit states (SLS)

(1) Combinations of actions for serviceability limit states, for which 8.4.2 and the general Formula (8.28) apply, should be chosen according to Table A.5.2, depending on the combinations of actions being considered.

Table A.5.2 — Combinations of actions for serviceability limit states

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Combinations** | **Characteristic** | **Frequent** | **Quasi-permanent** | **Seismic**b |
| **General formula effects of actions** | **(8.28)** | | | |
| **Formula for combination of actions** | **(8.29)** | **(8.30)** | **(8.31)** | **(8.32)** |
| Permanent actions (*G*d,*i*) | 𝐺k,*i* | 𝐺k,*i* | 𝐺k,*i* | 𝐺k,*i* |
| Leading variable action (*Q*d,1)a | 𝑄k,1 | *ψ*1,1𝑄k,1 | *ψ*2,*j*𝑄k,*j* | *ψ*2,*j*𝑄k,*j* |
| Accompanying variable actions (*Q*d,*j*) | *ψ*0,*j*𝑄k,*j* | *ψ*2,*j*𝑄k,*j* |
| Prestressing (*P*d) | 𝑃k | 𝑃k | 𝑃k | 𝑃k |
| Seismic (*A*Ed) | - | - | - | 𝐴Ed,SLS |
| a Leading variable action can be either crane specific or not.  b Depending on the magnitude of *A*Ed,SLS, the seismic combination of actions covers both damage limitation (DL) and fully operational (OP) serviceability limit states defined in EN 1998 (all parts). | | | | |

* + - 1. Combination factors

(1) Combinations of actions may be calculated using the combination factors *ψ*, as defined in 6.1.2.3(3).

NOTE Values of the combination factors *ψ* for structures supporting cranes and other machines are given in Table A.5.3 (NDP) unless the National Annex gives different values.

Table A.5.3 (NDP) — Combination factors for structures supporting cranes and other machines

|  |  |  |  |
| --- | --- | --- | --- |
| **Action**a | ***ψ*0** | ***ψ*1** | ***ψ*2** |
| Variable crane actions | 1,0 | 0,9 | 0 |
| Variable machine actions | 1,0 | 0,9 | 0,8 |
| In-service wind | 1,0 | 0,9 | 0 |
| a For other actions, see the relevant Annex A Clause. | | | |

* + 1. Partial factors
       1. Ultimate limit states (ULS)

(1) Ultimate limit states, excluding fatigue, may be verified using partial factors *γ*F applied to actions or *γ*E applied to effects of actions, as defined in 8.3.

NOTE 1 Values of the partial factor *γ*F for new, existing and rehabilitated structures are as given in Table A.5.4 (NDP), unless the National Annex gives different values.

NOTE 2 For fatigue, see 5.3.3.6 and A.5.8.

(2) The value of the partial factors *γ*F when applied to unfavourable actions or actions effects shall not be less than 1,0.

(3) Ultimate limit states that involve structural resistance should be verified using partial factors for verification case VC1.

(4) When variations in the magnitude or spatial variation of permanent actions from the same source are significant, ultimate limit states that involve loss of static equilibrium should be verified using partial factors for verification cases VC2(a) and VC2(b), using whichever gives the less favourable design outcome.

(5) Verification VC2(b) may be omitted when it is obvious that VC2(a) governs the design outcome.

(6) Ultimate limit states that involve failure of ground should be verified using partial factors for verification cases VC1, VC2, VC3 and VC4, in accordance with the relevant part of EN 1997.

NOTE EN 1997 (all parts) gives guidance on which verification cases to use for different geotechnical structures.

Table A.5.4 (NDP) — Partial factors on actions for structures supporting cranes and other machines

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Action or effect** | | | | **Partial factors *γ*F and *γ*E for verification cases** | | | | |
| **Type** | **Group** | **Symbol** | **Resulting effect** | **Structural resistance** | **Static equilibrium and uplift** | | **Geotechnical design** | |
| **Verification case** | | | | **VC1**a | **VC2(a)**b | **VC2(b)**b | **VC3**c | **VC4**d |
| Permanent actions (*G*k) | Allf | *γ*G | unfavourable  /destabilizing | 1,35*k*F | 1,35*k*F | 1,0 | 1,0 | *G*k is not factored |
| Water | *γ*G,w | 1,2*k*F | 1,2*k*F | 1,0 | 1,0 |
| Allf | *γ*G,stbe | stabilizingg | not used | 1,15e | 1,0 | not used |
| Water | *γ*G,w,stb | 1,0e | 1,0 |
| All | *γ*G,fav | favourableh | 1,0 | 1,0 | 1,0 | 1,0 |
| Prestressing  (*P*k) |  | *γ*Pk |  |  |  |  |  |  |
| Crane/machine variable action  (*Q*k) | All | *γ*Q | unfavourablei | 1,35*k*F | 1,35*k*F | 1,35*k*F | 1,15 | 1,0 |
| favourable | 0 | | | | |
| Variable action  (*Q*k) | Allf | *γ*Q | unfavourable | f | f | f | f | f, j |
| Water | *γ*Q,w | 1,35*k*F | 1,35*k*F | 1,35*k*F | 1,15 | 1,0 |
| All | *γ*Q,fav | favourable | 0 | | | | |
| Effects of actions  (*E*) | | *γ*E | unfavourable | *γ*E is not applied | | | | 1,35*k*F |
| *γ*E,fav | favourable | 1,0 |
| a Verification case VC1 is used both for structural and geotechnical design. Formula (8.4) is used for VC1.  b Verification case VC2 is used for the combined verification of strength and static equilibrium, when the structure is sensitive to variations in permanent action arising from a single-source. Values of *γ*F are taken from columns (a) or (b), whichever gives the less favourable outcome. Formula (8.4) is used for VC2.  c Verification case VC3 is typically used for the design of slopes and embankments, spread foundations, and gravity retaining structures. See EN 1997 (all parts) for details. Formula (8.4) is used for VC3.  d Verification case VC4 is typically used for the design of transversally loaded piles and embedded retaining walls and (in some countries) gravity retaining structures. See EN 1997 (all parts) for details. Formula (8.5) is used for VC4.  e The values of *γ*G,stb = 1,15 and 1,0 are based on *γ*G,inf = 1,35*ρ* and 1,2ρ with *ρ* = 0,85.  f See the relevant Clause of Annex A.  g Applied to the stabilizing component of an action originating from a single source.  h Applied to actions whose entire effect is favourable and independent of the unfavourable action.  i Applied also in test load conditions, unless the National Annex provides a different value.  j *γ*Q,1 = corresponding value of *γ*Q from VC1 and *γ*G,1 = corresponding value of *γ*G from VC1.  k See other relevant Eurocodes for the definition of *γ*P where *γ*P is materially dependent. | | | | | | | | |

* + - 1. Serviceability limit states (SLS)

(1) The values of partial factors for serviceability limit states should be taken as 1,0.

* + 1. Serviceability criteria

(1) The serviceability criteria should be defined in relation to the serviceability requirements in accordance with 5.4.

(2) Deformations should be calculated in accordance with other Eurocodes, by using the appropriate combinations of actions (see Table A.5.2 and Table A.5.3) taking into account the serviceability requirements and the distinction between reversible and irreversible limit states.

NOTE Minimum serviceability requirements and criteria can be defined in the National Annex.

(3) Additional appropriate serviceability requirements and criteria should be as specified by the relevant authority or, where not specified, agreed for a specific project by the relevant parties.

(4) For the verification of the serviceability limit states for the functioning of the crane or the machine, the verification should take into account the effects of the relevant variable actions.

(5) When tests are performed, the test loading of the crane should be taken into account as the crane action.

NOTE See for example EN 1991-3.

* + 1. Fatigue

(1) The fatigue verifications should be performed as specified in the other Eurocodes.

NOTE See also EN 1991-3, when relevant.

(2) For fatigue design situations the action spectrum and the expected number of cycles during the design life shall be considered, according to the specified service conditions of the crane or the machine.

(3) Fatigue load models for cranes should be chosen depending on the class of the load spectrum and on the total number of cycles, as specified in EN 13001-1:2015, Clause 4.

NOTE Classification of load spectrum according to EN 13001-1 depends on:

— classes of stress history *Si*;

— classes *Un* of the total number of working cycles during the design life of the crane, *Cn*;

— stress spectrum factor, 𝑘, taking into account all tasks of the crane.

(4) When multiple crane actions are relevant, they should be considered in the evaluation of the stress history.

(5) For cranes travelling on fixed runways, the simplified spectrum given in prEN 1991-3:2024, 2.12 may be adopted.

(6) Stress histories on fatigue sensitive details should be determined taking into account the variation of crane positions during the notional working cycle.

(7) When fatigue damage depends on the mean stress or strain of the cycle, effects should be determined considering the combination of actions given by Formula (8.17), being 𝐹fat the fatigue actions. In that case, permanent and variable actions considered in 𝐹fat should not be considered in the remainder of the combination.

(8) For normal service conditions of the crane the fatigue loads may be expressed in terms

of fatigue damage equivalent actions 𝐹fat,eq.

NOTE For determining fatigue load effects, 𝐹fat,eq can be assumed constant during each working cycle.

* 1. Application for coastal structures
     1. Use of this annex

(1) This Clause A.6 contains additional provisions to the general rules in Clauses 1 to 8 for the structures specified in A.6.2.

* + 1. Scope and field of application

(1) This Clause A.6 should be used for the design of coastal structures under design approach DA1.

(2) When a structure falls into the field of application of different parts of Annex A, these parts should be applied in conjunction, as specified by the relevant authority or agreed for a specific project by the relevant parties.

NOTE Protective coastal structures are assemblies of parts or elements that fulfil structural as well as other than structural (shelter) functions. They are very often designed experimentally using series of reduced scale model tests. Periodic maintenance procedures are often implemented that depend on the type of structure – for example rubble mound protective layers are subjected to substantial inspection and maintenance plans. Their reliability levels can deviate from the global reliability targets presented in Annex C.

* + 1. Consequence classes

(1) Coastal structures should be classified into consequence classes, according to the consequences of their failure as described in 4.3.

NOTE Examples of coastal structures in different consequence classes are given in Table A.6.1 (NDP), unless the National Annex gives different examples.

Table A.6.1 (NDP) — Examples of marine coastal structures in different consequence classes

| **Consequence class**a | **Description of consequences** | **Examples** |
| --- | --- | --- |
| CC3 | High | Coastal structures protecting port facilities which in case of failure have potential high economic, social or environmental losses, e.g. import/ export of important goods.  Structures with regulated access to visitors / strollers (e.g. land connected sensitive breakwaters whose public access is closed during storms); manned (trained personnel) structures. |
| CC2 | Normal | Coastal structures protecting port/terminal installations not belonging to another Consequence Class.  Structures with regulated access to visitors / strollers (e.g. ordinary piers whose public access is closed during storms). |
| CC1 | Low | Structures supporting or protecting infrastructure or properties which in case of failure have lower economic, social or environmental losses (e.g. a single pile supporting a less important navigation marker).  Structures with no public access and whose access is occasionally limited to trained personnel (e.g. less important coastal breakwaters, submerged structures). |
| a For provisions concerning CC0 and CC4, see 4.3. | | |

* + 1. Design service life

(1) The design service life *T*lf of a coastal structure, as described in 4.5, should be specified.

NOTE The value of *T*lf is given in Table A.6.2 (NDP) for different categories of coastal structures, unless the National Annex gives different values or categories.

(2) The design service life should be used to determine the time-dependent performance of the structure.

Table A.6.2 (NDP) — Design service life categories for coastal structure

|  |  |
| --- | --- |
| **Category of coastal structure** | **Design service life *T*lf**  years |
| Coastal structures including breakwaters, protecting infrastructure of nationally or internationally significant strategic or economic value. | 100 |
| Common coastal structures including breakwaters protecting commercial and industrial ports.  Common shore protection structures. | 50 |
| Structures dedicated to non-renewable natural resources, petrochemicals or similar industrial or commercial applications. | 25 |
| Temporary structures such as construction material import/ export facilities, temporary works during construction such as cofferdams, other structures with short life such as for a one-off event, or the structure itself during construction. | ≤ 10 |

* + 1. Actions

(1) The actions to be included in the design of coastal structures shall be those defined by EN 1991 (all parts, EN 1991-1-8 in particular), EN 1997 (all parts) and EN 1998 (all parts).

NOTE The design approaches for coastal structures are defined in EN 1991-1-8.

(2) For design approach DA1 the characteristic value of the action from currents and waves is defined by a return period which shall be adjusted by an importance factor φI that depends on the consequence class and the design service life of the structure.

(3) For design approaches DA2 the design values of actions and resistances are directly determined by probabilistic calculations so as to achieve the target reliability level assigned to the consequence class over the reference period (one year or 50 years or life time).

(4) For design approach DA3 target reliability levels are determined in a risk-informed method.

* + 1. Combinations of actions
       1. Ultimate limit states (ULS)

(1) Combination of actions for ultimate limit states with factors on actions shall be chosen depending on the design situation, according to:

— Table A.6.3, when using Formula (8.12); or

— Table A.6.4, when using Formula (8.13); or

— Table A.6.5, when using Formula (8.14).

NOTE 1 The formula to be used is Formula (8.12), unless the National Annex gives a different choice, see 8.3.4.2(2).

NOTE 2 The value of *ξ* in Table A.6.4 and Table A.6.5 is 0,85, unless the National Annex gives a different value, see 8.3.4.2(2), Note 2.

(2) If design values of actions for persistent and transient design situations are chosen according to Table A.6.4 or Table A.6.5, then both combinations (a and b) shall be verified.

Table A.6.3 — Combinations of actions for ultimate limit states when using Formula (8.12)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Design situation** | **Persistent and transient (fundamental)** | **Accidental**a | **Seismic**b | **Fatigue**c |
| **General formula** | **(8.4)** | | | |
| **Formula for combination of actions** | **(8.12)** | **(8.15)** | **(8.16)** | **(8.17)** |
| Permanent (*G*d,*i*) | 𝛾G,*i*𝐺k,*i* | 𝐺k,*i* | 𝐺k,*i* | 𝐺k,*i* |
| Leading variable (Qd,1) | 𝛾Q,1𝑄k,1 | 𝜓1,1𝑄k,1 or 𝜓2,1𝑄k,1 | 𝜓2,*j*𝑄k,*j* | 𝜓2,*j*𝑄k,*j* |
| Accompanying variable (Qd,*j*) | 𝛾Q,*j*𝜓0,*j*𝑄k,*j* | 𝜓2,*j*𝑄k,*j* |
| Accidental (Ad) | - | 𝐴d | - | - |
| Seismic (AEd) | - | - | 𝐴Ed,ULS | - |
| Fatigue (Ffat) | - | - | - | Ffat |
| a In accidental design situations, the choice between *ψ*1 and *ψ*2 depends on details of the design situation, e.g. ship collision, accidental metocean events (see prEN 1991-1-8:2024, 4.9), iceberg-collision. Further guidance can be given in the other Eurocodes and in the National Annex.  b Depending on the magnitude of *A*Ed,ULS, the seismic combination of actions covers both the near collapse (NC) and significant damage (SD) ultimate limit states defined in EN 1998 (all parts).  c See 8.3.4.5 for conditions of use. | | | | |

Table A.6.4 — Combinations of actions for ultimate limit states when using Formulae (8.13)

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Design situation** | **Persistent and transient (fundamental)** | | **Accidental** | **Seismic** | **Fatigue** |
| General formula | (8.4) | | | | |
| Formula for combination of actions | The upper part of (8.13) | The lower part of (8.13) | use values given in Table A.6.3 | | |
| Permanent (*G*d,*i*) | 𝛾G,*i*𝐺k,*i* | 𝜉𝛾G,*i*𝐺k,*i* |
| Leading variable (Qd,1) | 𝛾Q,*j*𝜓0,*j*𝑄k,*j* | 𝛾Q,1𝑄k,1 |
| Accompanying variable (Qd,*j*) | 𝛾Q,*j*𝜓0,*j*𝑄k,*j* |
| Accidental (*A*d) | - | - |
| Seismic (*A*Ed) | - | - |

Table A.6.5 — Combinations of actions for ultimate limit states when using Formula (8.14)

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Design situation** | **Persistent and transient (fundamental)** | | **Accidental** | **Seismic** | **Fatigue** |
| General formula | (8.4) | | | | |
| Formula for combination of actions | The upper part of (8.14) | The lower part of (8.14) | use values given in Table A.6.3 | | |
| Permanent (*G*d,*i*) | 𝛾G,*i*𝐺k,*i* | 𝜉𝛾G,*i*𝐺k,*i* |
| Leading variable (Qd,1) | - | 𝛾Q,1𝑄k,1 |
| Accompanying variable (Qd,*j*) | 𝛾Q,*j*𝜓0,*j*𝑄k,*j* |
| Accidental (*A*d) | - | - |
| Seismic (*A*Ed) | - | - |

(3) Combination of actions for ultimate limit states with partial factors on effects of actions should be chosen according to 8.3.2.3.

NOTE As defined in 8.3.2.3, Formula (8.5) applies when partial factors on effects of actions are used.

* + - 1. Serviceability limit states (SLS)

(1) Combinations of actions for serviceability limit states, for which 8.4.2 and the general formula (8.28) apply, should be chosen according to Table A.6.6, depending on the combinations of actions being considered.

Table A.6.6 — Combinations of actions for serviceability limit states

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Combinations** | **Characteristic** | **Frequent** | **Quasi- permanent** | **Seismic**a |
| General formula | (8.28) | | | |
| Formula for combination of actions | (8.29) | (8.30) | (8.31) | (8.32) |
| Permanent (*G*d,*i*) | 𝐺k,*i* | 𝐺k,*i* | 𝐺k,*i* | 𝐺k,*i* |
| Leading variable (*Q*d,1) | 𝑄k,1 | 𝜓1,1𝑄k,1 | 𝜓2,*j*𝑄k,*j* | 𝜓2,*j*𝑄k,*j* |
| Accompanying variable (*Q*d,*j*) | 𝜓0,*j*𝑄k,*j* | 𝜓2,*j*𝑄k,*j* |
| Seismic (*A*Ed) | - | - | - | 𝐴Ed,SLS |
| a Depending on the magnitude of *A*Ed,SLS, the seismic combination of actions covers both the damage limitation (DL) and fully operational (OP) serviceability limit states defined in EN 1998 (all parts). | | | | |

* + - 1. Combination factors

(1) Combinations values of actions may be calculated using the combination factors *ψ*, as defined in 6.1.2.3(3).

NOTE 1 Values of the combination factors *ψ* are as given in Table A.6.7 (NDP), unless the National Annex gives different values.

Table A.6.7 (NDP) — Combination factors for coastal structures

|  |  |  |  |
| --- | --- | --- | --- |
| **Action** | ***ψ*0** | ***ψ*1** | ***ψ*2** |
| Hydrodynamic loads (waves and currents)a | 0,7b | 0,2 | 0,05 |
| Traffic loads (according to the traffic category, see EN 1991-2) | See Clause A.2 | | |
| Construction actions | See Clause A.1 | | |
| Wind loads (see EN 1991-1-4)c | 0,6 | 0,2 | 0 |
| Snow loads and imposed loads | See Clause A.1 | | |
| Thermal actions (see EN 1991-1-5) | 0,6 | 0,5 | 0 |
| Atmospheric icing (see EN 1991-1-9)d | 0,5 | 0,2 | 0 |
| a The frequent and quasi-permanent values of the action from waves and currents can alternatively be determined directly by considering appropriate values of the return period of the metocean events or appropriate exceedance frequencies over a reference period, see EN 1991-1-8.  b This *ψ*0 value holds for the combination with non-metocean actions. The water levels, for instance, are taken into account in the calculation of hydrodynamic loads.  c The combination factors are meant for wind loads applied directly to the coastal structure or to an element thereof (like a seawall) or to a building that would rest on it (like a lighthouse). The wind conditions considered in the calculation of the wind loads on structures shall always be physically consistent with those considered in the calculation of the hydrodynamic loads on the same structures or structural parts.  d Sea icing and drifting sea ice are not addressed in EN 1991-1-9. | | | |

NOTE 2 Specific interaction (or combination) rules between metocean parameters (especially swell wave, wind waves, water levels, wind set-up, wave set-up, currents) for the calculation of the action from waves and currents, are given in EN 1991-1-8.

* + 1. Partial factors for ultimate limit states (ULS)

(1) Ultimate limit states shall be verified using partial factors *γ*F applied to actions or partial factors *γ*E applied to effects of actions, as defined in 8.3.

NOTE 1 Values of the partial factors *γ*F and *γ*E for new, existing and rehabilitated structures are given in Table A.6.8 (NDP) for persistent and transient design situations, unless the National Annex gives different values.

NOTE 2 Values of the consequence factor *k*F for metocean actions are equal to 1,0 since consequences are already included in the importance factor *φ*I. See A.6.6(2).

NOTE 3 Values of consequence factors *k*F multiplying the partial factors with consideration to the consequence class defined in Table A.6.1 (NDP) for actions other than metocean actions, are given in Table A.6.9 (NDP), unless the National Annex gives different values.

NOTE 4 For fatigue, see 8.3.3.6.

(2) The values of the partial factors *γ*F and *γ*E when applied to unfavourable actions or unfavourable action effects shall not be less than 1,0.

(3) Ultimate limit states of coastal structures loaded by waves and currents should be verified using partial factors for verification case VC1.

NOTE 1 Ultimate limit states for hydraulic design of coastal structures refer to:

— the hydraulic instabilities and erosion of the ground presented in EN 1997 (all parts);

— the severe displacement (SDi) of protecting armour units, seabed protections and all sorts of rubble or rip rap materials, and the severe wave overtopping limit state, presented in EN 1991-1-8.

NOTE 2 Ultimate limit states for structural design of coastal structures can refer to the resistance of blocks and armour units, on one hand, and to the limit states presented in EN 1992 (all parts) for concrete and in EN 1993 (all parts) for steel construction, on the other hand.

NOTE 3 Protection layers of coastal rubble mound structures are made of assemblies of armour units, either natural or man-made. The structural resistance of armour units and the adequacy with the marine environment stand outside of the Eurocodes.

(4) Verification cases for ultimate limit states for geotechnical design shall be in accordance with EN 1997 (all parts).

NOTE Ultimate limit states for geotechnical design of coastal structures can refer to bearing capacity, sliding, tilting, etc. Designing with acceptable deformations is actually a common practice in coastal engineering: for example assuming that a threshold of tilting or sliding of a vertical faced breakwater can be accepted, or a degree of a pile deformation.

(5) When variations in the magnitude or spatial variation of permanent actions from the same source are significant, ultimate limit states that involve loss of static equilibrium can be verified using partial factors for verification cases VC2(a) and VC2(b), using the whichever gives the less favourable design outcome.

(6) Verification case VC2(b) may be omitted when it is obvious that verification case VC2(a) governs the design outcome.

Table A.6.8 (NDP) — Partial factors on actions and on effects for the fundamental combination in persistent and transient design situations

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Action or effect** | | | | **Partial factors *γ*F and *γ*E for verification cases** | | | | |
| **Type** | **Group** | **Symbol** | **Resulting effect** | **Structural and hydraulic design** | **Static equilibrium and uplift** | | **Geotechnical design** | |
| **Verification case** | | | | **VC1**a | **VC2(a)**b | **VC2(b)**b | **VC3**c | **VC4**d |
| Perma-nent action  (*G*k) | All | *γ*G | unfavourable  /destabilizing | 1,35*k*F | 1,35*k*F | 1,0 | 1,0 | *G*k is not factored |
| All | *γ*G,stb | stabilizingf | not used | 1,15e | 1,0 | not used |
| All | *γ*G,fav | favourableg | 1,0 | 1,0 | 1,0 | 1,0 |
| Variable action  (*Q*k) | Hydrodynamic loads (waves, currents) | *γ*QH | unfavourable | 1,35h | 1,35 | 1,35 | 1,3 | *γ*Q,redi |
| Water levels | *γ*Qw | unfavourable | not factored | | | | |
| Other variable actions | *γ*Q | unfavourable | 1,5*k*F | 1,5*k*F | 1,5*k*F | 1,3 | *γ*Q,redi |
| All | *γ*Q,fav | favourable | 0 | | | | |
| Effects of actions (*E*) | | *γ*E | unfavourable | Effects of hydrodynamic actions on floating structures are factored by 1,35 | | | | 1,35 |
| *γ*E,fav | favourable | 1,0 |
| a Verification case VC1 is typically used for the structural, hydraulic and geotechnical design. Formula (8.4) is used for VC1.  b Verification case VC2 is typically used for the combined verification of strength and static equilibrium, when the structure is sensitive to variations in permanent action arising from a single source. Values of γF are taken from columns (a) or (b), whichever gives the less favourable outcome. Formula (8.4) is used for VC2.  c Verification case VC3 is typically used in some countries for the design of slopes and embankments, spread foundations, and gravity retaining structures. See EN 1997 (all parts) for details. Formula (8.4) is used for VC3.  d Verification case VC4 is typically used when it is relevant to apply partial factors on actions together with a partial factor on effects of actions (see EN 1997 (all parts) for details). Formula (8.5) is used for VC4.  e The value of *γ*G,stb = 1,15 is based on *γ*G,inf = 1,35*ρ* with *ρ* = 0,85.  f Applied to the stabilizing part of an action originating from a single source.  g Applied to actions whose entire effect is favourable and independent of the unfavourable action.  h For the verification of ultimate limit states in the hydraulic design of rubble mound breakwaters (such as the severe displacement ultimate limit state (SDi) of protecting armour units or the severe wave overtopping ultimate limit state), the design value of the hydrodynamic load is determined directly as a nominal value according to a high return period, without partial factor on the action, see 4.3(1), Note 8 and EN 1991-1-8.  i *γ*Q,red = *γ*Q,1/ *γ*G,1 where *γ*Q,1 = corresponding value of *γ*Q from VC1 and *γ*G,1 = corresponding value of *γ*G from VC1. | | | | | | | | |

Table A.6.9 (NDP) — Consequence factors for actions other than metocean actions

|  |  |  |
| --- | --- | --- |
| **Consequence class CC** | **Description of consequences** | **Consequence factor**  ***k*F** |
| CC3 | High | 1,1 |
| CC2 | Normal | 1,0 |
| CC1 | Low | 0,9 |

* + 1. Serviceability criteria

(1) Due care should be taken for possible effects of the coastal and marine environment on the durability and maintenance of the coastal structure.

(2) Serviceability criteria and relevant combinations of actions (characteristic, frequent or quasi-permanent) should be specified for each coastal marine project in accordance with 5.4.

NOTE 1 Serviceability criteria for coastal marine structures can include, for example, differential settlement, allowable wave overtopping discharge, allowable concrete crack width, decompression of the foundation, tilting, creep stability, downtime operational rates. See also EN 1992 (all parts) to EN 1999 (all parts).

NOTE 2 Criteria for the limited displacement serviceability limit state (LDi) and limited wave overtopping of protecting armour units are proposed in EN 1991-1-8.

NOTE 3 Specifications by relevant authorities or project-specific provisions can complement the serviceability criteria mentioned in the Eurocodes.

(3) Due care should be taken assessing the extent of water-structure interactions through analysis of wave run-up, wave overtopping and air gap as far as these affect the structure robustness.

# Modifications to B.1, Use of this annex

*Add a new paragraph (2):*

“(2) This Annex can also be used for assessment of existing structures.”

# Modifications to C.3.4.1, General

*In paragraph (3), add a new Note 2 in the end, then renumber the first note as Note 1:*

“NOTE 2 The target reliability level for existing and rehabilitated structures can be lower than that for new structures as the relative cost of safety measures to increase reliability of an existing structure is greater than that for a new structure.”

# Modifications to C.3.4.2, Criterion for reliability-based design and assessment

*In paragraph (3), replace Note 1 with the following:*

“NOTE 1 The target values of reliability index *β* for the 1-year and 50-year reference periods for persistent and transient (fundamental) and fatigue design situations in ULS for new, existing and rehabilitated structures included in the scope of Clauses A.1 and A.2 are given in Table C.3 (NDP), unless the National Annex gives different values.”

*In paragraph (3), add a new Note 5 in the end:*

“NOTE 5 For target values for reliability index *β* for seismic design situations, see EN 1998-1-1.”

# Modifications to C.4.5, Combination of variable actions

*In the explanation to Formula (C.24) in paragraph (1), replace the symbol* Φ *with the symbol* Φ()*.”*

# Modifications to G.7.4.3, Design movement due to permanent effects

*In the paragraph (2), replace the symbol d*execution *with the symbol d*exe.

# Modifications to the Bibliography

*Replace the bibliography with the following:*

Bibliography

**References contained in recommendations (i.e. “should” clauses)**

The following documents are referred to in the text in such a way that some or all of their content constitutes highly recommended choices or course of action of this document. Subject to national regulation and/or any relevant contractual provisions, alternative documents could be used/adopted where technically justified. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

prEN 1991‑3:2024, Eurocode 1 — Actions on structures — Part 3: Actions induced by cranes and machines

EN 13001‑1:2015, Cranes — General design — Part 1: General principles and requirements

**References contained in possibilities (i.e. “can” clauses) and notes**

The following documents are cited informatively in the document, for example in “can” clauses and in notes.

EN 40 (all parts), Lighting columns

EN 1337 (all parts), Structural bearings

EN 15129, Anti-seismic devices

EN 50341 (all parts), Overhead electrical lines exceeding AC 1 kV

EN IEC 61400 (all parts), Wind energy generation systems

ISO 2394:2015, General principles on reliability for structures

ISO 3898:2013, Bases for design of structures — Names and symbols of physical quantities and generic quantities

ISO 6707‑1:2020, Buildings and civil engineering works — Vocabulary — Part 1: General terms

EN ISO 9000:2015, Quality management systems — Fundamentals and vocabulary (ISO 9000:2015)

ISO 10137, Bases for design of structures — Serviceability of buildings and walkways against vibrations

ISO 12491, Statistical methods for quality control of building materials and components