

Eurocode — Basis of structural design

ICS 91.010.30; 91.080.01

National foreword

This British Standard is the UK implementation of EN 1990:2002+A1:2005, incorporating corrigenda December 2008 and April 2010. It supersedes DD ENV 1991-1:1996 which is withdrawn.

The start and finish of text introduced or altered by amendment is indicated in the text by tags. Tags indicating changes to CEN text carry the number of the CEN amendment. For example, text altered by CEN amendment A1 is indicated by A1 A1.

The start and finish of text introduced or altered by corrigendum is indicated in the text by tags. Text altered by CEN corrigendum December 2008 is indicated in the text by AC1 AC1.

The start and finish of text introduced or altered by corrigendum is indicated in the text by tags. Text altered by CEN corrigendum April 2010 is indicated in the text by AC2 AC2.

The UK participation in its preparation was entrusted by Technical Committee B/525, Building and Civil engineering structures, to Subcommittee B/525/1, Action, loadings and basis of design.

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

Where a normative part of this EN allows for a choice to be made at the national level, the range and possible choice will be given in the normative text, and a Note will qualify it as a Nationally Determined Parameter (NDP). NDPs can be a specific value for a factor, a specific level or class, a particular method or a particular application rule if several are proposed in the EN.

To enable EN 1990 to be used in the UK, the NDPs will be published in a National Annex which will be incorporated by amendment into this British Standard in due course, after public consultation has taken place.

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

Compliance with a British Standard cannot confer immunity from legal obligations.

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English version

Eurocode - Basis of structural design

Eurocodes structuraux - Eurocodes: Bases de calcul des structures

Eurocode: Grundlagen der Tragwerksplanung

This European Standard was approved by CEN on 29 November 2001.

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

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Foreword

This document (EN 1990:2002) has been prepared by Technical Committee CEN/TC 250 "Structural Eurocodes", the secretariat of which is held by BSI.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by October 2002, and conflicting national standards shall be withdrawn at the latest by March 2010.

This document supersedes ENV 1991-1:1994.

CEN/TC 250 is responsible for all Structural Eurocodes.

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

Foreword to amendment A1

This European Standard (EN 1990:2002/A1:2005) has been prepared by Technical Committee CEN/TC 250 "Structural Eurocodes", the secretariat of which is held by BSI.

This Amendment to the EN 1990:2002 shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by June 2006, and conflicting national standards shall be withdrawn at the latest by June 2006.

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

Background of the Eurocode programme

In 1975, the Commission of the European Community decided on an action programme in the field of construction, based on article 95 of the Treaty. The objective of the programme was the elimination of technical obstacles to trade and the harmonisation of technical specifications.

Within this action programme, the Commission took the initiative to establish a set of harmonised technical rules for the design of construction works which, in a first stage, would serve as an alternative to the $\langle AC_2 \rangle$ national provisions $\langle AC_2 \rangle$ in force in the Member States and, ultimately, would replace them.

For fifteen years, the Commission, with the help of a Steering Committee with Representatives of Member States, conducted the development of the Eurocodes programme, which led to the first generation of European codes in the 1980's.

In 1989, the Commission and the Member States of the EU and EFTA decided, on the basis of an agreement¹ between the Commission and CEN, to transfer the preparation and the publication of the Eurocodes to CEN through a series of Mandates, in order to provide them with a future status of European Standard (EN). This links *de facto* the Eurocodes with the provisions of all the Council's Directives and/or Commission's Decisions dealing with European standards (e.g. the Council Directive 89/106/EEC on construction products - CPD - and $\langle AC_2 \rangle$ Council Directives 2004/17/EC and 2004/18/EC $\langle AC_2 \rangle$ on public works and services and equivalent EFTA Directives initiated in pursuit of setting up the internal market).

The Structural Eurocode programme comprises the following standards generally consisting of a number of Parts:

EN 1990	Eurocode :	Basis of Structural Design
EN 1991	Eurocode 1:	Actions on structures
EN 1992	Eurocode 2:	Design of concrete structures
EN 1993	Eurocode 3:	Design of steel structures
EN 1994	Eurocode 4:	Design of composite steel and concrete structures
EN 1995	Eurocode 5:	Design of timber structures
EN 1996	Eurocode 6:	Design of masonry structures
EN 1997	Eurocode 7:	Geotechnical design
EN 1998	Eurocode 8:	Design of structures for earthquake resistance
EN 1999	Eurocode 9:	Design of aluminium structures

Eurocode standards recognise the responsibility of regulatory authorities in each Member State and have safeguarded their right to determine values related to regulatory safety matters at national level where these continue to vary from State to State.

¹ Agreement between the Commission of the European Communities and the European Committee for Standardisation (CEN) concerning the work on EUROCODES for the design of building and civil engineering works (BC/CEN/03/89).

Status and field of application of Eurocodes

The Member States of the EU and EFTA recognise that Eurocodes serve as reference documents for the following purposes :

- as a means to prove compliance of building and civil engineering works with the essential requirements of Council Directive 89/106/EEC, particularly Essential Requirement N°1 – Mechanical resistance and stability – and Essential Requirement N°2 – Safety in case of fire ;
- as a basis for specifying contracts for construction works and related engineering services ;
- as a framework for drawing up harmonised technical specifications for construction products (ENs and ETAs)

The Eurocodes, as far as they concern the construction works themselves, have a direct relationship with the Interpretative Documents² referred to in Article 12 of the CPD, although they are of a different nature from harmonised product standards³. Therefore, technical aspects arising from the Eurocodes work need to be adequately considered by CEN Technical Committees and/or EOTA Working Groups working on product standards **EN** and ETAGs **ETA** with a view to achieving a full compatibility of these technical specifications with the Eurocodes.

The Eurocode standards provide common structural design rules for everyday use for the design of whole structures and **EN** parts of works and structural construction **ETA** products of both a traditional and an innovative nature. Unusual forms of construction or design conditions are not specifically covered and additional expert consideration will be required by the designer in such cases.

National Standards implementing Eurocodes

The National Standards implementing Eurocodes will comprise the full text of the Eurocode (including any annexes), as published by CEN, which may be preceded by a National title page and National foreword, and may be followed by a National annex.

The National annex may only contain information on those parameters which are left open in the Eurocode for national choice, known as Nationally Determined Parameters, to be used for the design of buildings and civil engineering works to be constructed in the country concerned, i.e. :

² According to Art. 3.3 of the CPD, the essential requirements (ERs) shall be given concrete form in interpretative documents for the creation of the necessary links between the essential requirements and the mandates for harmonised ENs and ETAGs/ETAs.

³ According to Art. 12 of the CPD the interpretative documents shall :

- give concrete form to the essential requirements by harmonising the terminology and the technical bases and indicating classes or levels for each requirement where necessary ;
- indicate methods of correlating these classes or levels of requirement with the technical specifications, e.g. methods of calculation and of proof, technical rules for project design, etc. ;
- serve as a reference for the establishment of harmonised standards and guidelines for European technical approvals.

The Eurocodes, *de facto*, play a similar role in the field of the ER 1 and a part of ER 2.

- values and/or classes where alternatives are given in the Eurocode,
- values to be used where a symbol only is given in the Eurocode,
- country specific data (geographical, climatic, etc.), *e.g.* snow map,
- the procedure to be used where alternative procedures are given in the Eurocode.

It may also contain

- decisions on the application of informative annexes,
- references to non-contradictory complementary information to assist the user to apply the Eurocode.

Links between Eurocodes and harmonised technical specifications (ENs and ETAs) for products

There is a need for consistency between the harmonised technical specifications for construction products and the $\overline{AC_2}$ technical provisions $\overline{AC_2}$ for works⁴. Furthermore, all the information accompanying the CE Marking of the construction products which $\overline{AC_2}$ use the $\overline{AC_2}$ Euro-codes shall clearly mention which Nationally Determined Parameters have been taken into account.

Additional information specific to EN 1990

EN 1990 describes the Principles and requirements for safety, serviceability and durability of structures. It is based on the limit state concept used in conjunction with a partial factor method.

For the design of new structures, EN 1990 is intended to be used, for direct application, together with Eurocodes EN 1991 to 1999.

EN 1990 also gives guidelines for the aspects of structural reliability relating to safety, serviceability and durability :

- for design cases not covered by EN 1991 to EN 1999 (other actions, structures not treated, other materials) ;
- to serve as a reference document for other CEN TCs concerning structural matters.

EN 1990 is intended for use by :

- committees drafting standards for structural design and related product, testing and execution standards ;
- clients (*e.g.* for the formulation of their specific requirements on reliability levels and durability) ;
- designers and constructors ;
- relevant authorities.

EN 1990 may be used, when relevant, as a guidance document for the design of structures outside the scope of the Eurocodes EN 1991 to EN 1999, for :

- assessing other actions and their combinations ;
- modelling material and structural behaviour ;
- assessing numerical values of the reliability format.

⁴ see Art.3.3 and Art.12 of the CPD, as well as 4.2, 4.3.1, 4.3.2 and 5.2 of ID 1.

Numerical values for partial factors and other reliability parameters are recommended as basic values that provide an acceptable level of reliability. They have been selected assuming that an appropriate level of workmanship and of quality management applies. When EN 1990 is used as a base document by other CEN/TCs the same values need to be taken.

National annex for EN 1990

This standard gives alternative procedures, values and recommendations for classes with notes indicating where national choices may have to be made. Therefore the National Standard implementing EN 1990 should have a National annex containing all Nationally Determined Parameters to be used for the design of buildings and civil engineering works to be constructed in the relevant country.

AC2 National choice is allowed in EN 1990 Annex A1 through; AC2

- A1.1(1)
- A1.2.1(1)
- A1.2.2 (Table A1.1)
- A1.3.1(1) (Tables A1.2(A) to (C))
- A1.3.1(5)
- A1.3.2 (Table A1.3)
- A1.4.2(2)

AC2 National choice is allowed in EN 1990 Annex A2 through:

General clauses

Clause	Item
A2.1 (1) NOTE 3	Use of Table 2.1 : Design working life
A2.2.1(2) NOTE 1	Combinations involving actions which are outside the scope of EN 1991
A2.2.6(1) NOTE 1	Values of ψ factors
A2.3.1(1)	Alteration of design values of actions for ultimate limit states
A2.3.1(5)	Choice of Approach 1, 2 or 3
A2.3.1(7)	Definition of forces due to ice pressure
A2.3.1(8)	Values of χ factors for prestressing actions where not specified in the relevant design Eurocodes
A2.3.1 Table A2.4(A) NOTES 1 and 2	Values of γ factors
A2.3.1 Table A2.4(B)	- NOTE 1 : choice between 6.10 and 6.10a/b - NOTE 2 : Values of γ and ξ factors - NOTE 4 : Values of χ_{sd}

AC2

AC₂

A2.3.1 Table A2.4(C)	Values of γ factors
A2.3.2(1)	Design values in Table A2.5 for accidental designs situations, design values of accompanying variable actions and seismic design situations
A2.3.2 Table A2.5 NOTE	Design values of actions
A2.4.1(1) NOTE 1 (Table A2.6) NOTE 2	Alternative γ values for traffic actions for the serviceability limit state Infrequent combination of actions
A2.4.1(2)	Serviceability requirements and criteria for the calculation of deformations

Clauses specific for road bridges

Clause	Item
A2.2.2 (1)	Reference to the infrequent combination of actions
A2.2.2(3)	Combination rules for special vehicles
A2.2.2(4)	Combination rules for snow loads and traffic loads
A2.2.2(6)	Combination rules for wind and thermal actions
A2.2.6(1) NOTE 2	Values of $\psi_{1,infq}$ factors
A2.2.6(1) NOTE 3	Values of water forces

Clauses specific for footbridges

Clause	Item
A2.2.3(2)	Combination rules for wind and thermal actions
A2.2.3(3)	Combination rules for snow loads and traffic loads
A2.2.3(4)	Combination rules for footbridges protected from bad weather
A2.4.3.2(1)	Comfort criteria for footbridges

Clauses specific for railway bridges

Clause	Item
A2.2.4(1)	Combination rules for snow loading on railway bridges
A2.2.4(4)	Maximum wind speed compatible with rail traffic
A2.4.4.1(1) NOTE 3	Deformation and vibration requirements for temporary railway bridges
A2.4.4.2.1(4)P	Peak values of deck acceleration for railway bridges and associated frequency range
A2.4.4.2.2 – Table A2.7 NOTE	Limiting values of deck twist for railway bridges

AC₂

AC2	A2.4.4.2.2(3)P	Limiting values of the total deck twist for railway bridges
	A2.4.4.2.3(1)	Vertical deformation of ballasted and non ballasted railway bridges
	A2.4.4.2.3(2)	Limitations on the rotations of non-ballasted bridge deck ends for railway bridges
	A2.4.4.2.3(3)	Additional limits of angular rotations at the end of decks
	A2.4.4.2.4(2) – Table A2.8 NOTE 3	Values of α_i and r_i factors
	A2.4.4.2.4(3)	Minimum lateral frequency for railway bridges
	A2.4.4.3.2(6)	Requirements for passenger comfort for temporary bridges

AC2

Section 1 General

1.1 Scope

(1) EN 1990 establishes Principles and requirements for the safety, serviceability and durability of structures, describes the basis for their design and verification and gives guidelines for related aspects of structural reliability.

(2) EN 1990 is intended to be used in conjunction with EN 1991 to EN 1999 for the structural design of buildings and civil engineering works, including geotechnical aspects, structural fire design, situations involving earthquakes, execution and temporary structures.

NOTE For the design of special construction works (*e.g.* nuclear installations, dams, etc.), other provisions than those in EN 1990 to EN 1999 might be necessary.

(3) EN 1990 is applicable for the design of structures where other materials or other actions outside the scope of EN 1991 to EN 1999 are involved.

(4) EN 1990 is applicable for the structural appraisal of existing construction, in developing the design of repairs and alterations or in assessing changes of use.

NOTE Additional or amended provisions might be necessary where appropriate.

1.2 Normative references

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

NOTE The Eurocodes were published as European Prestandards. The following European Standards which are published or in preparation are cited in normative clauses :

EN 1991 Eurocode 1 : Actions on structures

EN 1992 Eurocode 2 : Design of concrete structures

EN 1993 Eurocode 3 : Design of steel structures

EN 1994 Eurocode 4 : Design of composite steel and concrete structures

EN 1995 Eurocode 5 : Design of timber structures

EN 1996 Eurocode 6 : Design of masonry structures

EN 1997 Eurocode 7 : Geotechnical design

EN 1998 Eurocode 8 : Design of structures for earthquake resistance

EN 1999 Eurocode 9 : Design of aluminium structures

1.3 Assumptions

(1) Design which employs the Principles and Application Rules is deemed to meet the requirements provided the assumptions given in EN 1990 to EN 1999 are satisfied (see Section 2).

(2) The general assumptions of EN 1990 are :

- the choice of the structural system and the design of the structure is made by appropriately qualified and experienced personnel;
- execution is carried out by personnel having the appropriate skill and experience;
- **AC2** – adequate supervision and quality control is provided during design and during execution of the work, i.e., factories, plants, and on site; **AC2**
- the construction materials and products are used as specified in EN 1990 or in EN 1991 to EN 1999 or in the relevant execution standards, or reference material or product specifications;
- the structure will be adequately maintained;
- the structure will be used in accordance with the design assumptions.

NOTE There may be cases when the above assumptions need to be supplemented.

1.4 Distinction between Principles and Application Rules

(1) Depending on the character of the individual clauses, distinction is made in EN 1990 between Principles and Application Rules.

(2) The Principles comprise :

- general statements and definitions for which there is no alternative, as well as ;
- requirements and analytical models for which no alternative is permitted unless specifically stated.

(3) The Principles are identified by the letter P following the paragraph number.

(4) The Application Rules are generally recognised rules which comply with the Principles and satisfy their requirements.

(5) It is permissible to use alternative design rules different from the Application Rules given in EN 1990 for works, provided that it is shown that the alternative rules accord with the relevant Principles and are at least equivalent with regard to the structural safety, serviceability and durability which would be expected when using the Eurocodes.

NOTE If an alternative design rule is substituted for an application rule, the resulting design cannot be claimed to be wholly in accordance with EN 1990 although the design will remain in accordance with the Principles of EN 1990. When EN 1990 is used in respect of a property listed in an Annex Z of a product standard or an ETAG, the use of an alternative design rule may not be acceptable for CE marking.

(6) In EN 1990, the Application Rules are identified by a number in brackets e.g. as this clause.

1.5 Terms and definitions

NOTE For the purposes of this European Standard, the terms and definitions are derived from ISO 2394, ISO 3898, ISO 8930, ISO 8402.

1.5.1 Common terms used in EN 1990 to EN 1999

1.5.1.1

construction works

everything that is constructed or results from construction operations

NOTE This definition accords with ISO 6707-1. The term covers both building and civil engineering works. It refers to the complete construction works comprising structural, non-structural and geotechnical elements.

1.5.1.2

type of building or civil engineering works

type of construction works designating its intended purpose, *e.g.* dwelling house, retaining wall, industrial building, road bridge

1.5.1.3

type of construction

indication of the principal structural material, *e.g.* reinforced concrete construction, steel construction, timber construction, masonry construction, steel and concrete composite construction

1.5.1.4

method of construction

manner in which the execution will be carried out, *e.g.* cast in place, prefabricated, cantilevered

1.5.1.5

construction material

material used in construction work, *e.g.* concrete, steel, timber, masonry

1.5.1.6

structure

organised combination of connected parts designed to carry loads and provide adequate rigidity

1.5.1.7

structural member

physically distinguishable part of a structure, *e.g.* a column, a beam, a slab, a foundation pile

1.5.1.8

form of structure

arrangement of structural members

NOTE Forms of structure are, for example, frames, suspension bridges.

1.5.1.9

structural system

load-bearing members of a building or civil engineering works and the way in which these members function together

1.5.1.10

structural model

idealisation of the structural system used for the purposes of analysis, design and verification

1.5.1.11

execution

all activities carried out for the physical completion of the work including procurement, the inspection and documentation thereof

NOTE The term covers work on site; it may also signify the fabrication of components off site and their subsequent erection on site.

1.5.2 Special terms relating to design in general

1.5.2.1

design criteria

quantitative formulations that describe for each limit state the conditions to be fulfilled

1.5.2.2

design situations

sets of physical conditions representing the real conditions occurring during a certain time interval for which the design will demonstrate that relevant limit states are not exceeded

1.5.2.3

transient design situation

design situation that is relevant during a period much shorter than the design working life of the structure and which has a high probability of occurrence

NOTE A transient design situation refers to temporary conditions of the structure, of use, or exposure, *e.g.* during construction or repair.

1.5.2.4

persistent design situation

design situation that is relevant during a period of the same order as the design working life of the structure

NOTE Generally it refers to conditions of normal use.

1.5.2.5

accidental design situation

design situation involving exceptional conditions of the structure or its exposure, including fire, explosion, impact or local failure

1.5.2.6

fire design

design of a structure to fulfil the required performance in case of fire

1.5.2.7

seismic design situation

design situation involving exceptional conditions of the structure when subjected to a seismic event

1.5.2.8

design working life

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

1.5.2.9

hazard

for the purpose of EN 1990 to EN 1999, an unusual and severe event, *e.g.* an abnormal action or environmental influence, insufficient strength or resistance, or excessive deviation from intended dimensions

1.5.2.10

load arrangement

identification of the position, magnitude and direction of a free action

1.5.2.11

load case

compatible load arrangements, sets of deformations and imperfections considered simultaneously with fixed variable actions and permanent actions for a particular verification

1.5.2.12

limit states

states beyond which the structure no longer fulfils the relevant design criteria

1.5.2.13

ultimate limit states

states associated with collapse or with other similar forms of structural failure

NOTE They generally correspond to the maximum load-carrying resistance of a structure or structural member.

1.5.2.14

serviceability limit states

states that correspond to conditions beyond which specified service requirements for a structure or structural member are no longer met

1.5.2.14.1

irreversible serviceability limit states

serviceability limit states where some consequences of actions exceeding the specified service requirements will remain when the actions are removed

1.5.2.14.2

reversible serviceability limit states

serviceability limit states where no consequences of actions exceeding the specified service requirements will remain when the actions are removed

1.5.2.14.3

serviceability criterion

design criterion for a serviceability limit state

1.5.2.15

resistance

capacity of a member or component, or a cross-section of a member or component of a structure, to withstand actions without mechanical failure *e.g.* bending resistance, buckling resistance, tension resistance

1.5.2.16

strength

mechanical property of a material indicating its ability to resist actions, usually given in units of stress

1.5.2.17

reliability

ability of a structure or a structural member to fulfil the specified requirements, including the design working life, for which it has been designed. Reliability is usually expressed in probabilistic terms

NOTE Reliability covers safety, serviceability and durability of a structure.

1.5.2.18

reliability differentiation

measures intended for the socio-economic optimisation of the resources to be used to build construction works, taking into account all the expected consequences of failures and the cost of the construction works

1.5.2.19

basic variable

part of a specified set of variables representing physical quantities which characterise actions and environmental influences, geometrical quantities, and material properties including soil properties

1.5.2.20

maintenance

set of activities performed during the working life of the structure in order to enable it to fulfil the requirements for reliability

NOTE Activities to restore the structure after an accidental or seismic event are normally outside the scope of maintenance.

1.5.2.21

repair

activities performed to preserve or to restore the function of a structure that fall outside the definition of maintenance

1.5.2.22

nominal value

value fixed on non-statistical bases, for instance on acquired experience or on physical conditions

1.5.3 Terms relating to actions

1.5.3.1

action (F)

- a) Set of forces (loads) applied to the structure (direct action);
- b) Set of imposed deformations or accelerations caused for example, by temperature changes, moisture variation, uneven settlement or earthquakes (indirect action).

1.5.3.2

effect of action (E)

effect of actions (or action effect) on structural members, (*e.g.* internal force, moment, stress, strain) or on the whole structure (*e.g.* deflection, rotation)

1.5.3.3

permanent action (G)

action that is likely to act throughout a given reference period and for which the variation in magnitude with time is negligible, or for which the variation is always in the same direction (monotonic) until the action attains a certain limit value

1.5.3.4

variable action (Q)

action for which the variation in magnitude with time is neither negligible nor monotonic

1.5.3.5

accidental action (A)

action, usually of short duration but of significant magnitude, that is unlikely to occur on a given structure during the design working life

NOTE 1 An accidental action can be expected in many cases to cause severe consequences unless appropriate measures are taken.

NOTE 2 Impact, snow, wind and seismic actions may be variable or accidental actions, depending on the available information on statistical distributions.

1.5.3.6

seismic action (A_E)

action that arises due to earthquake ground motions

1.5.3.7

geotechnical action

action transmitted to the structure by the ground, fill or groundwater

1.5.3.8

fixed action

action that has a fixed distribution and position over the structure or structural member such that the magnitude and direction of the action are determined unambiguously for the whole structure or structural member if this magnitude and direction are determined at one point on the structure or structural member

1.5.3.9

free action

action that may have various spatial distributions over the structure

1.5.3.10

single action

action that can be assumed to be statistically independent in time and space of any other action acting on the structure

1.5.3.11

static action

action that does not cause significant acceleration of the structure or structural members

1.5.3.12

dynamic action

action that causes significant acceleration of the structure or structural members

1.5.3.13

quasi-static action

dynamic action represented by an equivalent static action in a static model

1.5.3.14

characteristic value of an action (F_k)

principal representative value of an action

NOTE In so far as a characteristic value can be fixed on statistical bases, it is chosen so as to correspond to a prescribed probability of not being exceeded on the unfavourable side during a "reference period" taking into account the design working life of the structure and the duration of the design situation.

1.5.3.15

reference period

chosen period of time that is used as a basis for assessing statistically variable actions, and possibly for accidental actions

1.5.3.16

combination value of a variable action ($\psi_0 Q_k$)

value chosen - in so far as it can be fixed on statistical bases - so that the probability that the effects caused by the combination will be exceeded is approximately the same as by the characteristic value of an individual action. It may be expressed as a determined part of the characteristic value by using a factor $\psi_0 \leq 1$

1.5.3.17

frequent value of a variable action ($\psi_1 Q_k$)

value determined - in so far as it can be fixed on statistical bases - so that either the total time, within the reference period, during which it is exceeded is only a small given part of the reference period, or the frequency of it being exceeded is limited to a given value. It may be expressed as a determined part of the characteristic value by using a factor $\psi_1 \leq 1$

AC2 NOTE For the frequent value of multi-component traffic actions see load groups in EN 1991-2. **AC2**

1.5.3.18

quasi-permanent value of a variable action ($\psi_2 Q_k$)

value determined so that the total period of time for which it will be exceeded is a large fraction of the reference period. It may be expressed as a determined part of the characteristic value by using a factor $\psi_2 \leq 1$

1.5.3.19

accompanying value of a variable action (ψQ_k)

value of a variable action that accompanies the leading action in a combination

NOTE The accompanying value of a variable action may be the combination value, the frequent value or the quasi-permanent value.

1.5.3.20

representative value of an action (F_{rep})

value used for the verification of a limit state. A representative value may be the characteristic value (F_k) or an accompanying value (ψF_k)

1.5.3.21

design value of an action (F_d)

value obtained by multiplying the representative value by the partial factor γ

NOTE The product of the representative value multiplied by the partial factor $\gamma_F = \gamma_{Sd} \times \gamma_f$ may also be designated as the design value of the action (See 6.3.2).

1.5.3.22

combination of actions

set of design values used for the verification of the structural reliability for a limit state under the simultaneous influence of different actions

1.5.4 Terms relating to material and product properties

1.5.4.1

characteristic value (X_k or R_k)

value of a material or product property having a prescribed probability of not being attained in a hypothetical unlimited test series. This value generally corresponds to a specified fractile of the assumed statistical distribution of the particular property of the material or product. A nominal value is used as the characteristic value in some circumstances

1.5.4.2

design value of a material or product property (X_d or R_d)

value obtained by dividing the characteristic value by a partial factor γ_m or γ_M , or, in special circumstances, by direct determination

1.5.4.3

nominal value of a material or product property (X_{nom} or R_{nom})

value normally used as a characteristic value and established from an appropriate document such as a European Standard or Prestandard

1.5.5 Terms relating to geometrical data

1.5.5.1

characteristic value of a geometrical property (a_k)

value usually corresponding to the dimensions specified in the design. Where relevant, values of geometrical quantities may correspond to some prescribed fractiles of the statistical distribution

1.5.5.2

design value of a geometrical property (a_d)

generally a nominal value. Where relevant, values of geometrical quantities may correspond to some prescribed fractile of the statistical distribution

NOTE The design value of a geometrical property is generally equal to the characteristic value. However, it may be treated differently in cases where the limit state under consideration is very sensitive to the value of the geometrical property, for example when considering the effect of geometrical imperfections on buckling. In such cases, the design value will normally be established as a value specified directly, for example in an appropriate European Standard or Prestandard. Alternatively, it can be established from a statistical basis, with a value corresponding to a more appropriate fractile (e.g. a rarer value) than applies to the characteristic value.

1.5.6 Terms relating to structural analysis

NOTE The definitions contained in the clause may not necessarily relate to terms used in EN 1990, but are included here to ensure a harmonisation of terms relating to structural analysis for EN 1991 to EN 1999.

1.5.6.1

structural analysis

procedure or algorithm for determination of action effects in every point of a structure

NOTE A structural analysis may have to be performed at three levels using different models : global analysis, member analysis, local analysis.

1.5.6.2

global analysis

determination, in a structure, of a consistent set of either internal forces and moments, or stresses, that are in equilibrium with a particular defined set of actions on the structure, and depend on geometrical, structural and material properties

1.5.6.3

first order linear-elastic analysis without redistribution

elastic structural analysis based on linear stress/strain or moment/curvature laws and performed on the initial geometry

1.5.6.4

first order linear-elastic analysis with redistribution

linear elastic analysis in which the internal moments and forces are modified for structural design, consistently with the given external actions and without more explicit calculation of the rotation capacity

1.5.6.5

second order linear-elastic analysis

elastic structural analysis, using linear stress/strain laws, applied to the geometry of the deformed structure

1.5.6.6

first order non-linear analysis

structural analysis, performed on the initial geometry, that takes account of the non-linear deformation properties of materials

NOTE First order non-linear analysis is either elastic with appropriate assumptions, or elastic-perfectly plastic (see 1.5.6.8 and 1.5.6.9), or elasto-plastic (see 1.5.6.10) or rigid-plastic (see 1.5.6.11).

1.5.6.7

second order non-linear analysis

structural analysis, performed on the geometry of the deformed structure, that takes account of the non-linear deformation properties of materials

NOTE Second order non-linear analysis is either elastic-perfectly plastic or elasto-plastic.

1.5.6.8

first order elastic-perfectly plastic analysis

structural analysis based on moment/curvature relationships consisting of a linear elastic part followed by a plastic part without hardening, performed on the initial geometry of the structure

1.5.6.9

second order elastic-perfectly plastic analysis

structural analysis based on moment/curvature relationships consisting of a linear elastic part followed by a plastic part without hardening, performed on the geometry of the displaced (or deformed) structure

1.5.6.10

AC2 elasto-plastic analysis AC2

structural analysis that uses stress-strain or moment/curvature relationships consisting of a linear elastic part followed by a plastic part with or without hardening

NOTE In general, it is performed on the initial structural geometry, but it may also be applied to the geometry of the displaced (or deformed) structure.

1.5.6.11

rigid plastic analysis

analysis, performed on the initial geometry of the structure, that uses limit analysis theorems for direct assessment of the ultimate loading

NOTE The moment/curvature law is assumed without elastic deformation and without hardening.

1.6 Symbols

AC2 For the purposes of this European Standard, the following symbols apply.

NOTE The notation used is based on ISO 3898:1987.

Latin upper case letters

A	Accidental action
A_d	Design value of an accidental action
A_{Ed}	Design value of seismic action $A_{Ed} = \gamma_I A_{Ek}$
A_{Ek}	Characteristic value of seismic action
C_d	Nominal value, or a function of certain design properties of materials
E	Effect of actions
E_d	Design value of effect of actions
$E_{d,dst}$	Design value of effect of destabilising actions
$E_{d,stb}$	Design value of effect of stabilising actions
F	Action
F_d	Design value of an action
F_k	Characteristic value of an action
F_{rep}	Representative value of an action AC2

$\langle AC2 \rangle F_w$	Wind force (general symbol)
F_{wk}	Characteristic value of the wind force
F_w^*	Wind force compatible with road traffic
F_w^{**}	Wind force compatible with railway traffic
G	Permanent action
G_d	Design value of a permanent action
$G_{d,inf}$	Lower design value of a permanent action
$G_{d,sup}$	Upper design value of a permanent action
G_k	Characteristic value of a permanent action
$G_{k,j}$	Characteristic value of permanent action j
$G_{k,j,sup} /$ $G_{k,j,inf}$	Upper/lower characteristic value of permanent action j
G_{set}	Permanent action due to uneven settlements
P	Relevant representative value of a prestressing action (see EN 1992 to EN 1996 and EN 1998 to EN 1999)
P_d	Design value of a prestressing action
P_k	Characteristic value of a prestressing action
P_m	Mean value of a prestressing action
Q	Variable action
Q_d	Design value of a variable action
Q_k	Characteristic value of a single variable action
$Q_{k,1}$	Characteristic value of the leading variable action 1
$Q_{k,i}$	Characteristic value of the accompanying variable action i
Q_{Sn}	Characteristic value of snow load
R	Resistance
R_d	Design value of the resistance
R_k	Characteristic value of the resistance
T	Thermal climatic action (general symbol)
T_k	Characteristic value of the thermal climatic action
X	Material property
X_d	Design value of a material property
X_k	Characteristic value of a material property

Latin lower case letters

a_d	Design values of geometrical data
a_k	Characteristic values of geometrical data
a_{nom}	Nominal value of geometrical data
d_{set}	Difference in settlement of an individual foundation or part of a foundation compared to a reference level
u	Horizontal displacement of a structure or structural member
w	Vertical deflection of a structural member

Greek upper case letters

Δa	Change made to nominal geometrical data for particular design purposes, e.g. assessment of effects of imperfections
Δd_{set}	Uncertainty attached to the assessment of the settlement of a foundation or part of a foundation $\langle AC2 \rangle$

AC2 *Greek lower case letters*

γ	Partial factor (safety or serviceability)
γ_{bt}	Maximum peak value of bridge deck acceleration for ballasted track
γ_{df}	Maximum peak value of bridge deck acceleration for direct fastened track
γ_{Gset}	Partial factor for permanent actions due to settlements, also accounting for model uncertainties
γ	Partial factor for actions, which takes account of the possibility of unfavourable deviations of the action values from the representative values
γ_F	Partial factor for actions, also accounting for model uncertainties and dimensional variations
γ_g	Partial factor for permanent actions, which takes account of the possibility of unfavourable deviations of the action values from the representative values
γ_G	Partial factor for permanent actions, also accounting for model uncertainties and dimensional variations
$\gamma_{G,j}$	Partial factor for permanent action j
$\gamma_{G,j,sup} /$ $\gamma_{G,j,inf}$	Partial factor for permanent action j in calculating upper/lower design values
γ	Importance factor (see EN 1998)
γ_m	Partial factor for a material property
γ_M	Partial factor for a material property, also accounting for model uncertainties and dimensional variations
γ_P	Partial factor for prestressing actions (see EN 1992 to EN 1996 and EN 1998 to EN 1999)
γ_q	Partial factor for variable actions, which takes account of the possibility of unfavourable deviations of the action values from the representative values
γ_Q	Partial factor for variable actions, also accounting for model uncertainties and dimensional variations
$\gamma_{Q,i}$	Partial factor for variable action i
γ_{Rd}	Partial factor associated with the uncertainty of the resistance model
γ_{Sd}	Partial factor associated with the uncertainty of the action and/or action effect model
η	Conversion factor
ξ	Reduction factor
ψ_0	Factor for combination value of a variable action
ψ_1	Factor for frequent value of a variable action
ψ_2	Factor for quasi-permanent value of a variable action AC2

Section 2 Requirements

2.1 Basic requirements

(1)P A structure shall be designed and executed in such a way that it will, during its intended life, with appropriate degrees of reliability and in an economical way

- sustain all actions and influences likely to occur during execution and use, and
- ▣AC1 – meet the specified serviceability requirements for a structure or a structural element.

NOTE See also 1.3, 2.1(7) and 2.4(1) P. ▣AC1

(2)P A structure shall be designed to have adequate :

- structural resistance,
- serviceability, and
- durability.

(3)P In the case of fire, the structural resistance shall be adequate for the required period of time.

NOTE See also EN 1991-1-2

(4)P A structure shall be designed and executed in such a way that it will not be damaged by events such as :

- explosion,
 - impact, and
 - the consequences of human errors,
- to an extent disproportionate to the original cause.

NOTE 1 The events to be taken into account are those agreed for an individual project with the client and the relevant authority.

NOTE 2 Further information is given in EN 1991-1-7.

(5)P Potential damage shall be avoided or limited by appropriate choice of one or more of the following :

- avoiding, eliminating or reducing the hazards to which the structure can be subjected;
- selecting a structural form which has low sensitivity to the hazards considered ;
- selecting a structural form and design that can survive adequately the accidental removal of an individual member or a limited part of the structure, or the occurrence of acceptable localised damage ;
- avoiding as far as possible structural systems that can collapse without warning ;
- tying the structural members together.

(6) The basic requirements should be met :

- by the choice of suitable materials,
- by appropriate design and detailing, and
- by specifying control procedures for design, production, execution, and use relevant to the particular project.

(7) The provisions of Section 2 should be interpreted on the basis that due skill and care appropriate to the circumstances is exercised in the design, based on such knowledge and good practice as is generally available at the time that the design of the structure is carried out.

2.2 Reliability management

(1)P The reliability required for structures within the scope of EN 1990 shall be achieved:

- a) by design in accordance with EN 1990 to EN 1999 and
- b) by
 - appropriate execution and
 - quality management measures.

NOTE See 2.2(5) and Annex B

(2) Different levels of reliability may be adopted *inter alia* :

- for structural resistance ;
- for serviceability.

(3) The choice of the levels of reliability for a particular structure should take account of the relevant factors, including :

- the possible cause and /or mode of attaining a limit state ;
- the possible consequences of failure in terms of risk to life, injury, potential economical losses ;
- public aversion to failure ;
- the expense and procedures necessary to reduce the risk of failure.

(4) The levels of reliability that apply to a particular structure may be specified in one or both of the following ways :

- by the classification of the structure as a whole ;
- by the classification of its components.

NOTE See also Annex B

(5) The levels of reliability relating to structural resistance and serviceability can be achieved by suitable combinations of :

a) preventative and protective measures (e.g. implementation of safety barriers, active and passive protective measures against fire, protection against risks of corrosion such as painting or cathodic protection) ;

b) measures relating to design calculations :

- representative values of actions ;
- the choice of partial factors ;

c) measures relating to quality management ;

d) measures aimed to reduce errors in design and execution of the structure, and gross human errors ;

e) other measures relating to the following other design matters :

- the basic requirements ;
- the degree of robustness (structural integrity) ;
- durability, including the choice of the design working life ;
- the extent and quality of preliminary investigations of soils and possible environmental influences ;
- the accuracy of the mechanical models used ;
- the detailing ;

f) efficient execution, *e.g.* in accordance with execution standards referred to in EN 1991 to EN 1999.

g) adequate inspection and maintenance according to procedures specified in the project documentation.

(6) The measures to prevent potential causes of failure and/or reduce their consequences may, in appropriate circumstances, be interchanged to a limited extent provided that the required reliability levels are maintained.

2.3 Design working life

(1) The design working life should be specified.

NOTE Indicative categories are given in Table 2.1. The values given in Table 2.1 may also be used for determining time-dependent performance (*e.g.* fatigue-related calculations). See also Annex A.

Table 2.1 - Indicative design working life

Design working life category	Indicative design working life (years)	Examples
1	10	Temporary structures ⁽¹⁾
2	10 to 25	Replaceable structural parts, <i>e.g.</i> gantry girders, bearings
3	15 to 30	Agricultural and similar structures
4	50	Building structures and other common structures
5	100	Monumental building structures, bridges, and other civil engineering structures
(1) Structures or parts of structures that can be dismantled with a view to being re-used should not be considered as temporary.		

2.4 Durability

(1)P The structure shall be designed such that deterioration over its design working life does not impair the performance of the structure below that intended, having due regard to its environment and the anticipated level of maintenance.

(2) In order to achieve an adequately durable structure, the following should be taken into account :

- the intended or foreseeable use of the structure ;
- the required design criteria ;
- the expected environmental conditions ;
- the composition, properties and performance of the materials and products ;
- the properties of the soil ;
- the choice of the structural system ;
- the shape of members and the structural detailing ;
- the quality of workmanship, and the level of control ;
- the particular protective measures ;
- the intended maintenance during the design working life.

NOTE The relevant EN 1992 to EN 1999 specify appropriate measures to reduce deterioration.

(3)P The environmental conditions shall be identified at the design stage so that their significance can be assessed in relation to durability and adequate provisions can be made for protection of the materials used in the structure.

(4) The degree of any deterioration may be estimated on the basis of calculations, experimental investigation, experience from earlier constructions, or a combination of these considerations.

2.5 Quality management

(1) In order to provide a structure that corresponds to the requirements and to the assumptions made in the design, appropriate quality management measures should be in place. These measures comprise :

- definition of the reliability requirements,
- organisational measures and
- controls at the stages of design, execution, use and maintenance.

NOTE EN ISO 9001:2000 is an acceptable basis for quality management measures, where relevant.

Section 3 Principles of limit states design

3.1 General

(1)P A distinction shall be made between ultimate limit states and serviceability limit states.

NOTE In some cases, additional verifications may be needed, for example to ensure traffic safety.

(2) Verification of one of the two categories of limit states may be omitted provided that sufficient information is available to prove that it is satisfied by the other.

(3)P Limit states shall be related to design situations, see 3.2.

(4) Design situations should be classified as persistent, transient or accidental, see 3.2.

(5) Verification of limit states that are concerned with time dependent effects (*e.g.* fatigue) should be related to the design working life of the construction.

NOTE Most time dependent effects are cumulative.

3.2 Design situations

(1)P The relevant design situations shall be selected taking into account the circumstances under which the structure is required to fulfil its function.

(2)P Design situations shall be classified as follows :

- persistent design situations, which refer to the conditions of normal use ;
- transient design situations, which refer to temporary conditions applicable to the structure, *e.g.* during execution or repair ;
- accidental design situations, which refer to exceptional conditions applicable to the structure or to its exposure, *e.g.* to fire, explosion, impact or the consequences of localised failure ;
- seismic design situations, which refer to conditions applicable to the structure when subjected to seismic events.

NOTE Information on specific design situations within each of these classes is given in EN 1991 to EN 1999.

(3)P The selected design situations shall be sufficiently severe and varied so as to encompass all conditions that can reasonably be foreseen to occur during the execution and use of the structure.

3.3 Ultimate limit states

(1)P The limit states that concern :

- the safety of people, and/or
 - the safety of the structure
- shall be classified as ultimate limit states.

(2) In some circumstances, the limit states that concern the protection of the contents should be classified as ultimate limit states.

NOTE The circumstances are those agreed for a particular project with the client and the relevant authority.

(3) States prior to structural collapse, which, for simplicity, are considered in place of the collapse itself, may be treated as ultimate limit states.

(4)P The following ultimate limit states shall be verified where they are relevant :

- loss of equilibrium of the structure or any part of it, considered as a rigid body ;
- failure by excessive deformation, transformation of the structure or any part of it into a mechanism, rupture, loss of stability of the structure or any part of it, including supports and foundations ;
- failure caused by fatigue or other time-dependent effects.

AC2 NOTE Different sets of partial factors are associated with the various ultimate limit states, see 6.4.1. **AC2**

3.4 Serviceability limit states

(1)P The limit states that concern :

- the functioning of the structure or structural members under normal use ;
 - the comfort of people ;
 - the appearance of the construction works,
- shall be classified as serviceability limit states.

NOTE 1 In the context of serviceability, the term “appearance” is concerned with such criteria as high deflection and extensive cracking, rather than aesthetics.

NOTE 2 Usually the serviceability requirements are agreed for each individual project.

(2)P A distinction shall be made between reversible and irreversible serviceability limit states.

(3) The verification of serviceability limit states should be based on criteria concerning the following aspects :

- a) deformations that affect
 - the appearance,
 - the comfort of users, or
 - the functioning of the structure (including the functioning of machines or services),
- or that cause damage to finishes or non-structural members ;

- b) vibrations
 - that cause discomfort to people, or
 - that limit the functional effectiveness of the structure ;
- c) damage that is likely to adversely affect
 - the appearance,
 - the durability, or
 - the functioning of the structure.

NOTE Additional provisions related to serviceability criteria are given in the relevant EN 1992 to EN 1999.

3.5 Limit state design

(1)P Design for limit states shall be based on the use of structural and load models for relevant limit states.

(2)P It shall be verified that no limit state is exceeded when relevant design values for

- actions,
- material properties, or
- product properties, and
- geometrical data

are used in these models.

(3)P The verifications shall be carried out for all relevant design situations and load cases.

(4) The requirements of 3.5(1)P should be achieved by the partial factor method, described in section 6.

(5) As an alternative, a design directly based on probabilistic methods may be used.

NOTE 1 The relevant authority can give specific conditions for use.

NOTE 2 For a basis of probabilistic methods, see Annex C.

(6)P The selected design situations shall be considered and critical load cases identified.

(7) For a particular verification load cases should be selected, identifying compatible load arrangements, sets of deformations and imperfections that should be considered simultaneously with fixed variable actions and permanent actions.

(8)P Possible deviations from the assumed directions or positions of actions shall be taken into account.

(9) Structural and load models can be either physical models or mathematical models.

Section 4 Basic variables

4.1 Actions and environmental influences

4.1.1 Classification of actions

(1)P Actions shall be classified by their variation in time as follows :

- permanent actions (G), e.g. self-weight of structures, fixed equipment and road surfacing, and indirect actions caused by shrinkage and uneven settlements ;
- variable actions (Q), e.g. imposed loads on building floors, beams and roofs, wind actions or snow loads ;
- accidental actions (A), e.g. explosions, or impact from vehicles.

NOTE Indirect actions caused by imposed deformations can be either permanent or variable.

(2) Certain actions, such as seismic actions and snow loads, may be considered as either accidental and/or variable actions, depending on the site location, see EN 1991 and EN 1998.

(3) Actions caused by water may be considered as permanent and/or variable actions depending on the variation of their magnitude with time.

(4)P Actions shall also be classified

- by their origin, as direct or indirect,
- by their spatial variation, as fixed or free, or
- by their nature and/or the structural response, as static or dynamic.

(5) An action should be described by a model, its magnitude being represented in the most common cases by one scalar which may have several representative values.

NOTE For some actions and some verifications, a more complex representation of the magnitudes of some actions may be necessary.

4.1.2 Characteristic values of actions

(1)P The characteristic value F_k of an action is its main representative value and shall be specified :

- as a mean value, an upper or lower value, or a nominal value (which does not refer to a known statistical distribution) (see EN 1991) ;
- in the project documentation, provided that consistency is achieved with methods given in EN 1991.

(2)P The characteristic value of a permanent action shall be assessed as follows :

- if the variability of G can be considered as small, one single value G_k may be used ;
- if the variability of G cannot be considered as small, two values shall be used : an upper value $G_{k,sup}$ and a lower value $G_{k,inf}$.

(3) The variability of G may be neglected if G does not vary significantly during the design working life of the structure and its coefficient of variation is small. G_k should then be taken equal to the mean value.

NOTE This coefficient of variation can be in the range of 0,05 to 0,10 depending on the type of structure.

(4) In cases when the structure is very sensitive to variations in G (e.g. some types of prestressed concrete structures), two values should be used even if the coefficient of variation is small. Then $G_{k,inf}$ is the 5% fractile and $G_{k,sup}$ is the 95% fractile of the statistical distribution for G , which may be assumed to be Gaussian.

(5) The self-weight of the structure may be represented by a single characteristic value and be calculated on the basis of the nominal dimensions and mean unit masses, see EN 1991-1-1.

NOTE For the settlement of foundations, see EN 1997.

(6) Prestressing (P) should be classified as a permanent action caused by either controlled forces and/or controlled deformations imposed on a structure. These types of prestress should be distinguished from each other as relevant (e.g. prestress by tendons, prestress by imposed deformation at supports).

NOTE The characteristic values of prestress, at a given time t , may be an upper value $P_{k,sup}(t)$ and a lower value $P_{k,inf}(t)$. For ultimate limit states, a mean value $P_m(t)$ can be used. Detailed information is given in EN 1992 to EN 1996 and EN 1999.

(7)P For variable actions, the characteristic value (Q_k) shall correspond to either :

- an upper value with an intended probability of not being exceeded or a lower value with an intended probability of being achieved, during some specific reference period;
- a nominal value, which may be specified in cases where a statistical distribution is not known.

NOTE 1 Values are given in the various Parts of EN 1991.

NOTE 2 The characteristic value of climatic actions is based upon the probability of 0,02 of its time-varying part being exceeded for a reference period of one year. This is equivalent to a mean return period of 50 years for the time-varying part. However in some cases the character of the action and/or the selected design situation makes another fractile and/or return period more appropriate.

(8) For accidental actions the design value A_d should be specified for individual projects.

NOTE See also EN 1991-1-7.

(9) For seismic actions the design value A_{Ed} should be assessed from the characteristic value A_{Ek} or specified for individual projects.

NOTE See also EN 1998.

(10) For multi-component actions the characteristic action should be represented by groups of values each to be considered separately in design calculations.