SS EN 1998-1:2013(2021)+A1:2021

EN 1998-1:2004+A1:2013, IDT

(ICS 91.120.25)

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SINGAPORE STANDARD

Eurocode 8 : Design of structures for earthquake resistance

– Part 1 : General rules, seismic actions and rules for buildings

The national standard is the identical implementation of EN 1998-1:2004 and is adopted with permission of CEN, Rue de la Science 23 B - 1040 Brussels

Singapore Standards Council

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National Foreword

This Singapore Standard was prepared by the Technical Committee on Building Structure and Substructures under the purview of the Building and Construction Standards Committee.

This standard is an identical adoption of EN 1998-1 : 2004 'Eurocode 8 : Design of structures for earthquake resistance – Part 1: General rules, seismic actions and rules for buildings', including the amendments to this edition, published by European Committee for Standardization, CEN, Rue de la Science 23 B - 1040 Brussels.

Attention is drawn to the following:

– The Singapore Standards which implement international or European publications referred to in this document may be found in the SS Electronic Catalogue at: http://www.singaporestandardseshop.sg

The EN gives values with notes indicating where national choices may be made. Where a normative part of the EN allows for national choice to be made, 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.

The requirements of this SS EN 1998-1:2013(2021)+A1:2021 are to be read in conjunction with the Singapore National Annex (NA+A1:2021) to SS EN 1998-1:2013(2021)+A1:2021 which contains information on the Singapore Nationally Determined Parameters and is published separately.

Where the Importance Classes "I and II" and Importance Classes "III and IV" (e.g Table 4.3) appear in the standard, they should be read as classifications relating to "Ordinary" and "Special" buildings respectively in the local context (refer in the Singapore National Annex for SS EN 1998-1). The classification of "Special" building is used specifically for hospitals, fire stations, civil defence installations, ministry offices and institutional buildings.

National choice is allowed in EN 1998-1 through the following clauses:

– 2.1(1)P
– 2.1(1)P
– 3.1.1(4)
– 3.1.2(1)
– 3.2.1(1),(2),(3)
– 3.2.1(4)
– 3.2.1(5)
– 3.2.2.1(4)
– 3.2.2.2(1)P
– 3.2.2.3(1)P
– 3.2.2.5(4)P
– 4.2.3.2(8)
– 4.2.4(2)P
– 4.2.5(5)P
– 4.3.3.1(4)
– 4.3.3.1(8)
– 5.2.2.2(10)
– 5.2.4(1),(3)
– 5.4.3.5.2(1)
– 5.8.2(3)
– 5.8.2(4)
– 5.8.2(5)
– 5.11.1.3.2(3)
– 5.11.1.4
– 5.11.1.5(2)
– 5.11.3.4(7)e)
– 6.1.2(1)
– 6.1.3(1)
– 6.2(3)
– 6.2(7)
– 6.5.5(7)
– 6.7.4(2)
– 7.7.2(4)
– 8.3(1)
– 9.2.1(1)
– 9.2.2(1)
– 9.2.3(1)
– 9.2.4(1)
– 9.3(2)
– 9.3(2)
– 9.3(3)
– 9.3(4), Table 9.1
– 9.3(4), Table 9.1
– 9.5.1(5)
– 9.6(3)
– 9.7.2(1)
– 9.7.2(2)b)
– 9.7.2(2)c)

- 4.4.2.5(2)
- 4.4.3.2(2)
- 5.2.1(5)
- 7.1.2(1)
- 7.1.3(1),(3)
- 7.1.3(4)
- 9.7.2(5)
- 10.3(2)P

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

NOTE 1 – Where appropriate, the words “European Standard” are read as “Singapore Standard”.

NOTE 2 – Reference to International/Overseas Standards are replaced by applicable Singapore Standards or Technical References.

NOTE 3 – Where numerical values are expressed as decimals, the comma is read as a full point.

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

EUROPEAN STANDARD

NORME EUROPÉENNE

EUROPÄISCHE NORM

EN 1998-1

December 2004

ICS 91.120.25

Supersedes ENV 1998-1-1:1994, ENV 1998-1-2:1994, ENV 1998-1-3:1995

English version

Eurocode 8: Design of structures for earthquake resistance - Part 1: General rules, seismic actions and rules for buildings

Eurocode 8: Calcul des structures pour leur résistance aux séismes - Partie 1: Règles générales, actions sismiques et règles pour les bâtiments

Eurocode 8: Auslegung von Bauwerken gegen Erdbeben - Teil 1: Grundlagen, Erdbebeneinwirkungen und Regeln für Hochbauten

This European Standard was approved by CEN on 23 April 2004.

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

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 Central Secretariat has the same status as the official versions.

CEN members are the national standards bodies of 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.

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Foreword

This European Standard EN 1998-1, Eurocode 8: Design of structures for earthquake resistance: General rules, seismic actions and rules for buildings, 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.

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 June 2005, and conflicting national standards shall be withdrawn at latest by March 2010.

This document supersedes ENV 1998-1-1:1994, ENV 1998-1-2:1994 and ENV 1998-1-3:1995.

According to the CEN-CENELEC Internal Regulations, the National Standard Organisations 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 national rules 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 agreement[1] 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 Council Directives 93/37/EEC, 92/50/EEC and 89/440/EEC on public works and services and equivalent EFTA Directives initiated in pursuit of setting up the internal market).

[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).

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.

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 Documents[2] referred to in Article 12 of the CPD, although they are of a different nature from harmonised product standards[3]. Therefore, technical aspects arising from the Eurocodes work need to be adequately considered by

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[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 hENs and ETAGs/ETAs.

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

a) 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 ;

b) 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. ;

c) 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.

CEN Technical Committees and/or EOTA Working Groups working on product standards 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 component 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 (informative).

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. :

- 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 technical rules for works[4]. Furthermore, all the information accompanying the CE Marking of the construction products which refer to Eurocodes shall clearly mention which Nationally Determined Parameters have been taken into account.

Additional information specific to EN 1998-1

The scope of EN 1998 is defined in **1.1.1** and the scope of this Part of EN 1998 is defined in **1.1.2**. Additional Parts of EN 1998 are listed in **1.1.3**.

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[4] See Art.3.3 and Art.12 of the CPD, as well as clauses 4.2, 4.3.1, 4.3.2 and 5.2 of ID 1.

EN 1998-1 was developed from the merger of ENV 1998-1-1:1994, ENV 1998-1-2:1994 and ENV 1998-1-3:1995. As mentioned in **1.1.1**, attention must be paid to the fact that for the design of structures in seismic regions the provisions of EN 1998 are to be applied in addition to the provisions of the other relevant EN 1990 to EN 1997 and EN 1999.

One fundamental issue in EN 1998-1 is the definition of the seismic action. Given the wide difference of seismic hazard and seismo-genetic characteristics in the various member countries, the seismic action is herein defined in general terms. The definition allows various Nationally Determined Parameters (NDP) which should be confirmed or modified in the National Annexes.

It is however considered that, by the use of a common basic model for the representation of the seismic action, an important step is taken in EN 1998-1 in terms of Code harmonisation.

EN 1998-1 contains in its section related to masonry buildings specific provisions which simplify the design of "simple masonry buildings".

National annex for EN 1998-1

This standard gives alternative procedures, values and recommendations for classes with notes indicating where national choices may be made. Therefore the National Standard implementing EN 1998-1 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.

National choice is allowed in EN 1998-1:2004 through clauses:

Reference	Item
1.1.2(7)	Informative Annexes A and B.
2.1(1)P	Reference return period T_{NCR} of seismic action for the no-collapse requirement (or, equivalently, reference probability of exceedance in 50 years, P_{NCR}).
2.1(1)P	Reference return period T_{DLR} of seismic action for the damage limitation requirement. (or, equivalently, reference probability of exceedance in 10 years, P_{DLR}).
3.1.1(4)	Conditions under which ground investigations additional to those necessary for design for non-seismic actions may be omitted and default ground classification may be used.
3.1.2(1)	Ground classification scheme accounting for deep geology, including values of parameters S, T_B, T_C and T_D defining horizontal and vertical elastic response spectra in accordance with **3.2.2.2** and **3.2.2.3**.
3.2.1(1), (2),(3)	Seismic zone maps and reference ground accelerations therein.
3.2.1(4)	Governing parameter (identification and value) for threshold of low seismicity .

3.2.1(5)	Governing parameter (identification and value) for threshold of very low seismicity .
3.2.2.1(4), 3.2.2.2(1)P	Parameters *S*, T_B, T_C, T_D defining shape of horizontal elastic response spectra.
3.2.2.3(1)P	Parameters a_{vg} T_B, T_C, T_D defining shape of vertical elastic response spectra.
3.2.2.5(4)P	Lower bound factor β on design spectral values.
4.2.3.2(8)	Reference to definitions of centre of stiffness and of torsional radius in multi-storey buildings meeting or not conditions (a) and (b) of **4.2.3.2(8)**
4.2.4(2)P	Values of φ for buildings.
4.2.5(5)P	Importance factor γ_I for buildings.
4.3.3.1 (4)	Decision on whether nonlinear methods of analysis may be applied for the design of non-base-isolated buildings. Reference to information on member deformation capacities and the associated partial factors for the Ultimate Limit State for design or evaluation on the basis of nonlinear analysis methods.
4.3.3.1 (8)	Threshold value of importance factor, γ_I, relating to the permitted use of analysis with two planar models.
4.4.2.5 (2).	Overstrength factor γ_{Rd} for diaphragms.
4.4.3.2 (2)	Reduction factor ν for displacements at damage limitation limit state
5.2.1(5)	Geographical limitations on use of ductility classes for concrete buildings.
5.2.2.2(10)	q_o-value for concrete buildings subjected to special Quality System Plan.
5.2.4(1), (3)	Material partial factors for concrete buildings in the seismic design situation.
5.4.3.5.2(1)	Minimum web reinforcement of large lightly reinforced concrete walls
5.8.2(3)	Minimum cross-sectional dimensions of concrete foundation beams.
5.8.2(4)	Minimum thickness and reinforcement ratio of concrete foundation slabs.
5.8.2(5)	Minimum reinforcement ratio of concrete foundation beams.
5.11.1.3.2(3)	Ductility class of precast wall panel systems.
5.11.1.4	*q*-factors of precast systems.
5.11.1.5(2)	Seismic action during erection of precast structures.
5.11.3.4(7)e	Minimum longitudinal steel in grouted connections of large panel

	walls.
6.1.2(1)	Upper limit of q for low-dissipative structural behaviour concept; limitations on structural behaviour concept; geographical limitations on use of ductility classes for steel buildings.
6.1.3(1)	Material partial factors for steel buildings in the seismic design situation.
6.2(3)	Overstrength factor for capacity design of steel buildings.
6.2 (7)	Information as to how EN 1993-1-10:2004 may be used in the seismic design situation
6.5.5(7)	Reference to complementary rules on acceptable connection design
6.7.4(2)	Residual post-buckling resistance of compression diagonals in steel frames with V-bracings.
7.1.2(1)	Upper limit of q for low-dissipative structural behaviour concept; limitations on structural behaviour concept; geographical limitations on use of ductility classes for composite steel-concrete buildings.
7.1.3(1), (3)	Material partial factors for composite steel-concrete buildings in the seismic design situation.
7.1.3(4)	Overstrength factor for capacity design of composite steel-concrete buildings
7.7.2(4)	Stiffness reduction factor for concrete part of a composite steel-concrete column section
8.3(1)	Ductility class for timber buildings.
9.2.1(1)	Type of masonry units with sufficient robustness.
9.2.2(1)	Minimum strength of masonry units.
9.2.3(1)	Minimum strength of mortar in masonry buildings.
9.2.4(1)	Alternative classes for perpend joints in masonry
9.3(2)	Conditions for use of unreinforced masonry satisfying provisions of EN 1996 alone.
9.3(2)	Minimum effective thickness of unreinforced masonry walls satisfying provisions of EN 1996 alone.
9.3(3)	Maximum value of ground acceleration for the use of unreinforced masonry satisfying provisions of EN. 1998-1
9.3(4), Table 9.1	q-factor values in masonry buildings.
9.3(4), Table 9.1	q-factors for buildings with masonry systems which provide enhanced ductility.
9.5.1(5)	Geometric requirements for masonry shear walls.
9.6(3)	Material partial factors in masonry buildings in the seismic design situation.

9.7.2(1)	Maximum number of storeys and minimum area of shear walls of “simple masonry building”.
9.7.2(2)b	Minimum aspect ratio in plan of “simple masonry buildings”.
9.7.2(2)c	Maximum floor area of recesses in plan for “simple masonry buildings”.
9.7.2(5)	Maximum difference in mass and wall area between adjacent storeys of “simple masonry buildings”.
10.3(2)P	Magnification factor on seismic displacements for isolation devices.

1 GENERAL

1.1 Scope

1.1.1 Scope of EN 1998

(1)P EN 1998 applies to the design and construction of buildings and civil engineering works in seismic regions. Its purpose is to ensure that in the event of earthquakes:

– human lives are protected;

– damage is limited; and

– structures important for civil protection remain operational.

NOTE The random nature of the seismic events and the limited resources available to counter their effects are such as to make the attainment of these goals only partially possible and only measurable in probabilistic terms. The extent of the protection that can be provided to different categories of buildings, which is only measurable in probabilistic terms, is a matter of optimal allocation of resources and is therefore expected to vary from country to country, depending on the relative importance of the seismic risk with respect to risks of other origin and on the global economic resources.

(2)P Special structures, such as nuclear power plants, offshore structures and large dams, are beyond the scope of EN 1998.

(3)P EN 1998 contains only those provisions that, in addition to the provisions of the other relevant Eurocodes, must be observed for the design of structures in seismic regions. It complements in this respect the other Eurocodes.

(4) EN 1998 is subdivided into various separate Parts (see **1.1.2** and **1.1.3**).

1.1.2 Scope of EN 1998-1

(1) EN 1998-1 applies to the design of buildings and civil engineering works in seismic regions. It is subdivided in 10 Sections, some of which are specifically devoted to the design of buildings.

(2) Section **2** of EN 1998-1 contains the basic performance requirements and compliance criteria applicable to buildings and civil engineering works in seismic regions.

(3) Section **3** of EN 1998-1 gives the rules for the representation of seismic actions and for their combination with other actions. Certain types of structures, dealt with in EN 1998-2 to EN 1998-6, need complementing rules which are given in those Parts.

(4) Section **4** of EN 1998-1 contains general design rules relevant specifically to buildings.

(5) Sections **5** to **9** of EN 1998-1 contain specific rules for various structural materials and elements, relevant specifically to buildings as follows:

– Section **5**: Specific rules for concrete buildings;

– Section **6**: Specific rules for steel buildings;

– Section **7**: Specific rules for composite steel-concrete buildings;

– Section **8**: Specific rules for timber buildings;

– Section **9**: Specific rules for masonry buildings.

(6) Section **10** contains the fundamental requirements and other relevant aspects of design and safety related to base isolation of structures and specifically to base isolation of buildings.

NOTE Specific rules for isolation of bridges are developed in EN 1998-2.

(7) Annex C contains additional elements related to the design of slab reinforcement in steel-concrete composite beams at beam-column joints of moment frames.

NOTE Informative Annex A and informative Annex B contain additional elements related to the elastic displacement response spectrum and to target displacement for pushover analysis.

1.1.3 Further Parts of EN 1998

(1)P Further Parts of EN 1998 include, in addition to EN 1998-1, the following:

– EN 1998-2 contains specific provisions relevant to bridges;

– EN 1998-3 contains provisions for the seismic assessment and retrofitting of existing buildings;

– EN 1998-4 contains specific provisions relevant to silos, tanks and pipelines;

– EN 1998-5 contains specific provisions relevant to foundations, retaining structures and geotechnical aspects;

– EN 1998-6 contains specific provisions relevant to towers, masts and chimneys.

1.2 Normative References

(1)P 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).

1.2.1 General reference standards

EN 1990 Eurocode - Basis of structural design

EN 1992-1-1 Eurocode 2 – Design of concrete structures – Part 1-1: General – Common rules for building and civil engineering structures

EN 1993-1-1 Eurocode 3 – Design of steel structures – Part 1-1: General – General rules

EN 1994-1-1	Eurocode 4 – Design of composite steel and concrete structures – Part 1-1: General – Common rules and rules for buildings
EN 1995-1-1	Eurocode 5 – Design of timber structures – Part 1-1: General – Common rules and rules for buildings
EN 1996-1-1	Eurocode 6 – Design of masonry structures – Part 1-1: General –Rules for reinforced and unreinforced masonry
EN 1997-1	Eurocode 7 - Geotechnical design – Part 1: General rules

1.2.2 Reference Codes and Standards

(1)P For the application of EN 1998, reference shall be made to EN 1990, to EN 1997 and to EN 1999.

(2) EN 1998 incorporates other normative references cited at the appropriate places in the text. They are listed below:

ISO 1000	The international system of units (SI) and its application;
EN 1090-1	Execution of steel structures – Part 1: General rules and rules for buildings;
prEN 12512	Timber structures – Test methods – Cyclic testing of joints made with mechanical fasteners.

1.3 Assumptions

(1) In addition to the general assumptions of EN 1990:2002, **1.3**, the following assumption applies.

(2)P It is assumed that no change in the structure will take place during the construction phase or during the subsequent life of the structure, unless proper justification and verification is provided. Due to the specific nature of the seismic response this applies even in the case of changes that lead to an increase of the structural resistance.

1.4 Distinction between principles and application rules

(1) The rules of EN 1990:2002, **1.4** apply.

1.5 Terms and definitions

1.5.1 Terms common to all Eurocodes

(1) The terms and definitions given in EN 1990:2002, **1.5** apply.

1.5.2 Further terms used in EN 1998

(1) The following terms are used in EN 1998 with the following meanings:

behaviour factor
factor used for design purposes to reduce the forces obtained from a linear analysis, in order to account for the non-linear response of a structure, associated with the material, the structural system and the design procedures

capacity design method
design method in which elements of the structural system are chosen and suitably designed and detailed for energy dissipation under severe deformations while all other structural elements are provided with sufficient strength so that the chosen means of energy dissipation can be maintained

dissipative structure
structure which is able to dissipate energy by means of ductile hysteretic behaviour and/or by other mechanisms

dissipative zones
predetermined parts of a dissipative structure where the dissipative capabilities are mainly located

NOTE 1 These are also called critical regions.

dynamically independent unit
structure or part of a structure which is directly subjected to the ground motion and whose response is not affected by the response of adjacent units or structures

importance factor
factor which relates to the consequences of a structural failure

non-dissipative structure
structure designed for a particular seismic design situation without taking into account the non-linear material behaviour

non-structural element
architectural, mechanical or electrical element, system and component which, whether due to lack of strength or to the way it is connected to the structure, is not considered in the seismic design as load carrying element

primary seismic members
members considered as part of the structural system that resists the seismic action, modelled in the analysis for the seismic design situation and fully designed and detailed for earthquake resistance in accordance with the rules of EN 1998

secondary seismic members
members which are not considered as part of the seismic action resisting system and whose strength and stiffness against seismic actions is neglected

NOTE 2 They are not required to comply with all the rules of EN 1998, but are designed and detailed to maintain support of gravity loads when subjected to the displacements caused by the seismic design situation.

1.6 Symbols

1.6.1 General

(1) The symbols indicated in EN 1990:2002, **1.6** apply. For the material-dependent symbols, as well as for symbols not specifically related to earthquakes, the provisions of the relevant Eurocodes apply.

(2) Further symbols, used in connection with seismic actions, are defined in the text where they occur, for ease of use. However, in addition, the most frequently occurring symbols used in EN 1998-1 are listed and defined in **1.6.2** and **1.6.3**.

1.6.2 Further symbols used in Sections 2 and 3 of EN 1998-1

A_{Ed} design value of seismic action (= $\gamma_I . A_{Ek}$)

A_{Ek} characteristic value of the seismic action for the reference return period

E_d design value of action effects

N_{SPT} Standard Penetration Test blow-count

P_{NCR} reference probability of exceedance in 50 years of the reference seismic action for the no-collapse requirement

Q variable action

$S_e(T)$ elastic horizontal ground acceleration response spectrum also called "elastic response spectrum". At T=0, the spectral acceleration given by this spectrum equals the design ground acceleration on type A ground multiplied by the soil factor S.

$S_{ve}(T)$ elastic vertical ground acceleration response spectrum

$S_{De}(T)$ elastic displacement response spectrum

$S_d(T)$ design spectrum (for elastic analysis). At T=0, the spectral acceleration given by this spectrum equals the design ground acceleration on type A ground multiplied by the soil factor S

S soil factor

T vibration period of a linear single degree of freedom system

T_s duration of the stationary part of the seismic motion

T_{NCR} reference return period of the reference seismic action for the no-collapse requirement

a_{gR} reference peak ground acceleration on type A ground

a_g design ground acceleration on type A ground

a_{vg} design ground acceleration in the vertical direction

c_u undrained shear strength of soil

d_g design ground displacement

g acceleration of gravity

q behaviour factor

$v_{s,30}$ average value of propagation velocity of S waves in the upper 30 m of the soil profile at shear strain of 10^{-5} or less

γ_I importance factor

η damping correction factor

ξ viscous damping ratio (in percent)

$\psi_{2,i}$ combination coefficient for the quasi-permanent value of a variable action i

$\psi_{E,i}$ combination coefficient for a variable action i, to be used when determining the effects of the design seismic action

1.6.3 Further symbols used in Section 4 of EN 1998-1

E_E effect of the seismic action

E_{Edx}, E_{Edy} design values of the action effects due to the horizontal components (x and y) of the seismic action

E_{Edz} design value of the action effects due to the vertical component of the seismic action

F_i horizontal seismic force at storey i

F_a horizontal seismic force acting on a non-structural element (appendage)

F_b base shear force

H building height from the foundation or from the top of a rigid basement

L_{max}, L_{min} larger and smaller in plan dimension of the building measured in orthogonal directions

R_d design value of resistance

S_a seismic coefficient for non-structural elements

T_1 fundamental period of vibration of a building

T_a fundamental period of vibration of a non-structural element (appendage)

W_a weight of a non-structural element (appendage)

d displacement

d_r design interstorey drift

e_a accidental eccentricity of the mass of one storey from its nominal location

h interstorey height

m_i mass of storey i

n number of storeys above the foundation or the top of a rigid basement

q_a behaviour factor of a non-structural element (appendage)

q_d displacement behaviour factor

s_i displacement of mass m_i in the fundamental mode shape of a building

z_i height of mass m_i above the level of application of the seismic action

α ratio of the design ground acceleration to the acceleration of gravity

γ_a importance factor of a non-structural element (appendage)

γ_d overstrength factor for diaphragms

θ interstorey drift sensitivity coefficient

1.6.4 Further symbols used in Section 5 of EN 1998-1

A_c Area of section of concrete member

A_{sh} total area of horizontal hoops in a beam-column joint

A_{si} total area of steel bars in each diagonal direction of a coupling beam

A_{st} area of one leg of the transverse reinforcement

A_{sv} total area of the vertical reinforcement in the web of the wall

$A_{sv,i}$ total area of column vertical bars between corner bars in one direction through a joint

A_w total horizontal cross-sectional area of a wall

ΣA_{si} sum of areas of all inclined bars in both directions, in wall reinforced with inclined bars against sliding shear

ΣA_{sj} sum of areas of vertical bars of web in a wall, or of additional bars arranged in the wall boundary elements specifically for resistance against sliding shear

ΣM_{Rb} sum of design values of moments of resistance of the beams framing into a joint in the direction of interest

ΣM_{Rc} sum of design values of the moments of resistance of the columns framing into a joint in the direction of interest

D_o diameter of confined core in a circular column

$M_{i,d}$ end moment of a beam or column for the calculation of its capacity design shear

$M_{Rb,i}$ design value of beam moment of resistance at end *i*

$M_{Rc,i}$ design value of column moment of resistance at end *i*

N_{Ed} axial force from the analysis for the seismic design situation

T_1 fundamental period of the building in the horizontal direction of interest

T_C corner period at the upper limit of the constant acceleration region of the elastic spectrum

V'_{Ed} shear force in a wall from the analysis for the seismic design situation

V_{dd} dowel resistance of vertical bars in a wall

V_{Ed} design shear force in a wall

$V_{Ed,max}$ maximum acting shear force at end section of a beam from capacity design calculation

$V_{Ed,min}$ minimum acting shear force at end section of a beam from capacity design calculation

V_{fd} contribution of friction to resistance of a wall against sliding shear

V_{id} contribution of inclined bars to resistance of a wall against sliding shear

$V_{Rd,c}$ design value of shear resistance for members without shear reinforcement in accordance with EN1992-1-1:2004

$V_{Rd,S}$ design value of shear resistance against sliding

b width of bottom flange of beam

b_c cross-sectional dimension of column

b_{eff} effective flange width of beam in tension at the face of a supporting column

b_i distance between consecutive bars engaged by a corner of a tie or by a cross-tie in a column

b_o width of confined core in a column or in the boundary element of a wall (to centreline of hoops)

b_w thickness of confined parts of a wall section, or width of the web of a beam

b_{wo} thickness of web of a wall

d effective depth of section

d_{bL} longitudinal bar diameter

d_{bw} diameter of hoop

f_{cd} design value of concrete compressive strength

f_{ctm} mean value of tensile strength of concrete

f_{yd} design value of yield strength of steel

$f_{yd,h}$ design value of yield strength of the horizontal web reinforcement

$f_{yd,v}$ design value of yield strength of the vertical web reinforcement

f_{yld} design value of yield strength of the longitudinal reinforcement

f_{ywd} design value of yield strength of transverse reinforcement

h cross-sectional depth

h_c cross-sectional depth of column in the direction of interest

h_f flange depth

h_{jc} distance between extreme layers of column reinforcement in a beam-column joint

h_{jw} distance between beam top and bottom reinforcement

h_o depth of confined core in a column (to centreline of hoops)

h_s clear storey height

h_w height of wall or cross-sectional depth of beam

k_D factor reflecting the ductility class in the calculation of the required column depth for anchorage of beam bars in a joint, equal to 1 for DCH and to 2/3 for DCM

k_w factor reflecting the prevailing failure mode in structural systems with walls

l_{cl} clear length of a beam or a column

l_{cr} length of critical region

l_i	distance between centrelines of the two sets of inclined bars at the base section of walls with inclined bars against sliding shear
l_w	length of cross-section of wall
n	total number of longitudinal bars laterally engaged by hoops or cross ties on perimeter of column section
q_o	basic value of the behaviour factor
s	spacing of transverse reinforcement
x_u	neutral axis depth
z	internal lever arm
α	confinement effectiveness factor, angle between diagonal bars and axis of a coupling beam
α_o	prevailing aspect ratio of walls of the structural system
α_1	multiplier of horizontal design seismic action at formation of first plastic hinge in the system
α_u	multiplier of horizontal seismic design action at formation of global plastic mechanism
γ_c	partial factor for concrete
γ_{Rd}	model uncertainty factor on design value of resistances in the estimation of capacity design action effects, accounting for various sources of overstrength
γ_s	partial factor for steel
ε_{cu2}	ultimate strain of unconfined concrete
$\varepsilon_{cu2,c}$	ultimate strain of confined concrete
$\varepsilon_{su,k}$	characteristic value of ultimate elongation of reinforcing steel
$\varepsilon_{sy,d}$	design value of steel strain at yield
η	reduction factor on concrete compressive strength due to tensile strains in transverse direction
ζ	ratio, $V_{Ed,min}/V_{Ed,max}$, between the minimum and maximum acting shear forces at the end section of a beam
μ_f	concrete-to-concrete friction coefficient under cyclic actions
μ_ϕ	curvature ductility factor
μ_δ	displacement ductility factor
ν	axial force due in the seismic design situation, normalised to $A_c f_{cd}$
ξ	normalised neutral axis depth
ρ	tension reinforcement ratio
ρ'	compression steel ratio in beams
σ_{cm}	mean value of concrete normal stress

ρ_h reinforcement ratio of horizontal web bars in a wall

ρ_l total longitudinal reinforcement ratio

ρ_{max} maximum allowed tension steel ratio in the critical region of primary seismic beams

ρ_v reinforcement ratio of vertical web bars in a wall

ρ_w shear reinforcement ratio

ω_v mechanical ratio of vertical web reinforcement

ω_{wd} mechanical volumetric ratio of confining reinforcement

1.6.5 Further symbols used in Section 6 of EN 1998-1

L beam span

M_{Ed} design bending moment from the analysis for the seismic design situation

$M_{pl,RdA}$ design value of plastic moment resistance at end A of a member

$M_{pl,RdB}$ design value of plastic moment resistance at end B of a member

N_{Ed} design axial force from the analysis for the seismic design situation

$N_{Ed,E}$ axial force from the analysis due to the design seismic action alone

$N_{Ed,G}$ axial force due to the non-seismic actions included in the combination of actions for the seismic design situation

$N_{pl,Rd}$ design value of yield resistance in tension of the gross cross-section of a member in accordance with EN 1993-1-1:2004

$N_{Rd}(M_{Ed},V_{Ed})$ design value of axial resistance of column or diagonal in accordance with EN 1993-1-1:2004, taking into account the interaction with the bending moment M_{Ed} and the shear V_{Ed} in the seismic situation

R_d resistance of connection in accordance with EN 1993-1-1:2004

R_{fy} plastic resistance of connected dissipative member based on the design yield stress of material as defined in EN 1993-1-1:2004.

V_{Ed} design shear force from the analysis for the seismic design situation

$V_{Ed,G}$ shear force due to the non seismic actions included in the combination of actions for the seismic design situation

$V_{Ed,M}$ shear force due to the application of the plastic moments of resistance at the two ends of a beam

$V_{pl,Rd}$ design value of shear resistance of a member in accordance with EN 1993-1-1:2004

$V_{wp,Ed}$ design shear force in web panel due to the design seismic action effects

$V_{wp,Rd}$ design shear resistance of the web panel in accordance with EN 1993- 1-1:2004

e length of seismic link

f_y nominal yield strength of steel

$f_{y,max}$ maximum permissible yield stress of steel

q behaviour factor

t_w web thickness of a seismic link

t_f flange thickness of a seismic link

Ω multiplicative factor on axial force $N_{Ed,E}$ from the analysis due to the design seismic action, for the design of the non-dissipative members in concentric or eccentric braced frames per Cl. **6.7.4** and **6.8.3** respectively

α ratio of the smaller design bending moment $M_{Ed,A}$ at one end of a seismic link to the greater bending moments $M_{Ed,B}$ at the end where plastic hinge forms, both moments taken in absolute value

α_1 multiplier of horizontal design seismic action at formation of first plastic hinge in the system

α_u multiplier of horizontal seismic design action at formation of global plastic mechanism

γ_M partial factor for material property

γ_{ov} material overstrength factor

δ beam deflection at midspan relative to tangent to beam axis at beam end (see Figure 6.11)

γ_{pb} multiplicative factor on design value $N_{pl,Rd}$ of yield resistance in tension of compression brace in a V bracing, for the estimation of the unbalanced seismic action effect on the beam to which the bracing is connected

γ_s partial factor for steel

θ_p rotation capacity of the plastic hinge region

$\overline{\lambda}$ non-dimensional slenderness of a member as defined in EN 1993-1-1:2004

1.6.6 Further symbols used in Section 7 of EN 1998-1

A_{pl} horizontal area of the plate

E_a Modulus of Elasticity of steel

E_{cm} mean value of Modulus of Elasticity of concrete in accordance with EN 1992-1-1:2004

I_a second moment of area of the steel section part of a composite section, with respect to the centroid of the composite section

I_c second moment of area of the concrete part of a composite section, with respect to the centroid of the composite section

I_{eq} equivalent second moment of area of the composite section

I_s second moment of area of the rebars in a composite section, with respect to the centroid of the composite section

$M_{pl,Rd,c}$ design value of plastic moment resistance of column, taken as lower bound and computed taking into account the concrete component of the section and only the steel components of the section classified as ductile

$M_{U,Rd,b}$ upper bound plastic resistance of beam, computed taking into account the concrete component of the section and all the steel components in the section, including those not classified as ductile

$V_{wp,Ed}$ design shear force in web panel, computed on the basis of the plastic resistance of the adjacent dissipative zones in beams or connections

$V_{wp,Rd}$ design shear resistance of the composite steel-concrete web panel in accordance with EN 1994-1-1:2004

b width of the flange

b_b width of composite beam (see Figure 7.3a) or bearing width of the concrete of the slab on the column (see Figure 7.7).

b_e partial effective width of flange on each side of the steel web

b_{eff} total effective width of concrete flange

b_o width (minimum dimension) of confined concrete core (to centreline of hoops)

d_{bL} diameter of longitudinal rebars

d_{bw} diameter of hoops

f_{yd} design yield strength of steel

f_{ydf} design yield strength of steel in the flange

f_{ydw} design strength of web reinforcement

h_b depth of composite beam

h_c depth of composite column section

k_r rib shape efficiency factor of profiled steel sheeting

k_t reduction factor of design shear resistance of connectors in accordance with EN 1994-1-1:2004

l_{cl} clear length of column

l_{cr} length of critical region

n steel-to-concrete modular ratio for short term actions

q behaviour factor

r reduction factor on concrete rigidity for the calculation of the stiffness of composite columns

t_f thickness of flange

γ_c partial factor for concrete

γ_M partial factor for material property

γ_{ov} material overstrength factor

γ_s partial factor for steel

ε_a total strain of steel at Ultimate Limit State

ε_{cu2} ultimate compressive strain of unconfined concrete

η minimum degree of connection as defined in **6.6.1.2** of EN 1994-1-1:2004

1.6.7 Further symbols used in Section 8 of EN 1998-1

E_o Modulus of Elasticity of timber for instantaneous loading

b width of timber section

d fastener-diameter

h depth of timber beams

k_{mod} modification factor for instantaneous loading on strength of timber in accordance with EN 1995-1-1:2004

q behaviour factor

γ_M partial factor for material properties

1.6.8 Further symbols used in Section 9 of EN 1998-1

$a_{g,urm}$ upper value of the design ground acceleration at the site for use of unreinforced masonry satisfying the provisions of Eurocode 8

A_{min} total cross-section area of masonry walls required in each horizontal direction for the rules for "simple masonry buildings" to apply

$f_{b,min}$ normalised compressive strength of masonry normal to the bed face

$f_{bh,min}$ normalised compressive strength of masonry parallel to the bed face in the plane of the wall

$f_{m,min}$ minimum strength for mortar

h greater clear height of the openings adjacent to the wall

h_{ef} effective height of the wall

l length of the wall

n number of storeys above ground

$p_{A,min}$ Minimum sum of horizontal cross-sectional areas of shear walls in each direction, as percentage of the total floor area per storey

p_{max} percentage of the total floor area above the level

q behaviour factor

t_{ef} effective thickness of the wall

$\Delta_{A,max}$ maximum difference in horizontal shear wall cross-sectional area between adjacent storeys of "simple masonry buildings"

$\Delta_{m,max}$ maximum difference in mass between adjacent storeys of "simple masonry buildings"

γ_m partial factors for masonry properties

γ_s partial factor for reinforcing steel

λ_{min} ratio between the length of the small and the length of the long side in plan

1.6.9 Further symbols used in Section 10 of EN 1998-1

K_{eff} effective stiffness of the isolation system in the principal horizontal direction under consideration, at a displacement equal to the design displacement d_{dc}

K_V total stiffness of the isolation system in the vertical direction

K_{xi} effective stiffness of a given unit i in the x direction

K_{yi} effective stiffness of a given unit i in the y direction

T_{eff} effective fundamental period of the superstructure corresponding to horizontal translation, the superstructure assumed as a rigid body

T_f fundamental period of the superstructure assumed fixed at the base

T_V fundamental period of the superstructure in the vertical direction, the superstructure assumed as a rigid body

M mass of the superstructure

M_s magnitude

d_{dc} design displacement of the effective stiffness centre in the direction considered

d_{db} total design displacement of an isolator unit

$e_{tot,y}$ total eccentricity in the y direction

f_j horizontal forces at each level j

r_y torsional radius of the isolation system

(x_i,y_i) co-ordinates of the isolator unit i relative to the effective stiffness centre

δ_i amplification factor

ξ_{eff} “effective damping”

1.7 S.I. Units

(1)P S.I. Units in accordance with ISO 1000 shall be used.

(2) For calculations, the following units are recommended:

– forces and loads: kN, kN/m, kN/m^2
– unit mass: kg/m^3, t/m^3
– mass: kg, t
– unit weight: kN/m^3
– stresses and strengths: N/mm^2 (= MN/m^2 or MPa), kN/m^2 (=kPa)
– moments (bending, etc): kNm
– acceleration: m/s^2, g (=9,81 m/s^2)