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Eurokod 8: Dimensionering av bärverk med avseende på jordbävning – Del 2: Broar

Eurocode 8: Design of structures for earthquake resistance – Part 2: Bridges

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The European Standard EN 1998-2:2005 has the status of a Swedish Standard. The European Standard was 2005-12-16 implemented as SS-EN 1998-2:2005 and it is now published in English with the National Annexes NA and NB

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EUROPEAN STANDARD

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English Version

Eurocode 8 - Design of structures for earthquake resistance - Part 2: Bridges

Eurocode 8 - Calcul des structures pour leur résistance aux séismes - Partie 2: Ponts

Eurocode 8 - Auslegung von Bauwerken gegen Erdbeben - Teil 2: Brücken

This European Standard was approved by CEN on 7 July 2005.

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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 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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Contents Page

Foreword

This European Standard EN 1998-2, Eurocode 8: Design of structures for earthquake resistance: Bridges, has been prepared by Technical Committee CEN/TC250 «Structural Eurocodes», the Secretariat of which is held by BSI. CEN/TC250 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of an identical text or by endorsement, at the latest by May 2006, and conflicting national standards shall be withdrawn at latest by March 2010.

This document supersedes ENV 1998-2:1994.

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 1980s.

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

[2] In accordance with 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] In accordance with 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 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.

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 use of informative annexes, and

– 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 1998-2

The scope of this Part of EN 1998 is defined in **1.1**.

Except where otherwise specified in this Part, the seismic actions are as defined in EN 1998-1:2004, Section **3**.

[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.

Due to the peculiarities of the bridge seismic resisting systems, in comparison to those of buildings and other structures, all other sections of this Part are in general not directly related to those of EN 1998-1:2004. However several provisions of EN 1998-1:2004 are used by direct reference.

Since the seismic action is mainly resisted by the piers and the latter are usually constructed of reinforced concrete, a greater emphasis has been given to such piers.

Bearings are in many cases important parts of the seismic resisting system of a bridge and are therefore treated accordingly. The same holds for seismic isolation devices.

National annex for EN 1998-2

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 1998-2 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 1998-2:2005 through clauses:

Reference	Item
1.1.1(8)	Informative Annexes A, B, C, D, E, F, H and JJ
2.1(3)P	Reference return period T_{NCR} of seismic action for the no-collapse requirement of the bridge (or, equivalently, reference probability of exceedance in 50 years, P_{NCR}).
2.1(4)P	Importance classes for bridges
2.1(6)	Importance factors for bridges
2.2.2(5)	Conditions under which the seismic action may be considered as accidental action, and the requirements of **2.2.2(3)** and **2.2.2 (4)** may be relaxed.
2.3.5.3(1)	Expression for the length of plastic hinges
2.3.6.3(5)	Fractions of design displacements for non-critical structural elements
2.3.7(1)	Cases of low seismicity
2.3.7(1)	Simplified criteria for the design of bridges in cases of low seismicity
3.2.2.3	Definition of active fault
3.3(1)P	Length of continuous deck beyond which the spatial variability of seismic action may have to be taken into account
3.3(6)	Distance beyond which the seismic ground motions may be considered as completely uncorrelated
3.3(6)	factor accounting for the magnitude of ground displacements occurring in opposite direction at adjacent supports
4.1.2(4)P	ψ_{21} values for traffic loads assumed concurrent with the design seismic action

4.1.8(2)	Upper limit for the value in the left-hand-side of expression (4.4) for the seismic behaviour of a bridge to be considered irregular
5.3(4)	Value of ovestrength factor γ_o
5.4(1)	Simplified methods for second order effects in linear analysis
5.6.2(2)P b	Value of additional safety factor γ_{Bd1} on shear resistance
5.6.3.3(1)P b	Alternatives for determination of additional safety factor γ_{Bd} on shear resistance of ductile members outside plastic hinges
6.2.1.4(1)P	Type of confinement reinforcement
6.5.1(1)P	Simplified verification rules for bridges of limited ductile behaviour in low seismicity cases
6.6.2.3(3)	Allowable extent of damage of elastomeric bearings in bridges where the seismic action is considered as accidental action, but is not resisted entirely by elastomeric bearings
6.6.3.2(1)P	Percentage of the compressive (downward) reaction due to the permanent load that is exceeded by the total vertical reaction on a support due to the design seismic action, for holding-down devices to be required.
6.7.3(7)	Upper value of design seismic displacement to limit damage of the soil or embankment behind abutments rigidly connected to the deck.
7.4.1(1)P	Value of control period T_D for the design spectrum of bridges with seismic isolation
7.6.2(1)P	Value of amplication factor γ_{IS} on design displacement of isolator units
7.6.2(5)	Value of γ_m for elastomeric bearings
7.7.1(2)	Values of factors δ_w and δ_b for the lateral restoring capability of the isolation system
J.1(2)	Values of minimum isolator temperature in the seismic design situation
J.2(1)	Values of λ-factors for commonly used isolators

1 INTRODUCTION

1.1 Scope

1.1.1 Scope of EN 1998-2

(1) The scope of Eurocode 8 is defined in EN 1998-1:2004, **1.1.1** and the scope of this Standard is defined in **1.1.1**. Additional parts of Eurocode 8 are indicated in EN 1998-1:2004, **1.1.3**.

(2) Within the framework of the scope set forth in EN 1998-1:2004, this part of the Standard contains the particular Performance Requirements, Compliance Criteria and Application Rules applicable to the design of earthquake resistant bridges.

(3) This Part primarily covers the seismic design of bridges in which the horizontal seismic actions are mainly resisted through bending of the piers or at the abutments; i.e. of bridges composed of vertical or nearly vertical pier systems supporting the traffic deck superstructure. It is also applicable to the seismic design of cable-stayed and arched bridges, although its provisions should not be considered as fully covering these cases.

(4) Suspension bridges, timber and masonry bridges, moveable bridges and floating bridges are not included in the scope of this Part.

(5) This Part contains only those provisions that, in addition to other relevant Eurocodes or relevant Parts of EN 1998, should be observed for the design of bridges in seismic regions. In cases of low seismicity, simplified design criteria may be established (see **2.3.7(1)**).

(6) The following topics are dealt with in the text of this Part:

- Basic requirements and Compliance Criteria,
- Seismic Action,
- Analysis,
- Strength Verification,
- Detailing.

This Part also includes a special section on seismic isolation with provisions covering the application of this method of seismic protection to bridges.

(7) Annex G contains rules for the calculation of capacity design effects.

(8) Annex J contains rules regarding the variation of design properties of seismic isolator units and how such variation may be taken into account in design.

NOTE 1 Informative Annex A provides information for the probabilities of the reference seismic event and recommendations for the selection of the design seismic action during the construction phase.

NOTE 2 Informative Annex B provides information on the relationship between the displacement ductility and the curvature ductility of plastic hinges in concrete piers.

NOTE 3 Informative Annex C provides information for the estimation of the effective stiffness of reinforced concrete ductile members.

NOTE 4 Informative Annex D provides information for modelling and analysis for the spatial variability of earthquake ground motion.

NOTE 5 Informative Annex E gives information on probable material properties and plastic hinge deformation capacities for non-linear analyses.

NOTE 6 Informative Annex F gives information and guidance for the added mass of entrained water in immersed piers.

NOTE 7 Informative Annex H provides guidance and information for static non-linear analysis (pushover).

NOTE 8 Informative Annex JJ provides information on λ-factors for common isolator types.

NOTE 9 Informative Annex K contains tests requirements for validation of design properties of seismic isolator units.

1.1.2 Further parts of EN 1998

See EN 1998-1:2004.

1.2 Normative References

1.2.1 Use

(1)P The following normative documents contain provisions, which through references in this text, constitute provisions of this European standard. For dated references, subsequent amendments to or revisions of any of these publications do not apply. However, parties to agreements based on this European standard are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. For undated references the latest edition of the normative document referred to applies (including amendments).

1.2.2 General reference standards

EN 1998-1:2004, **1.2.1** applies.

1.2.3 Reference Codes and Standards

EN 1998-1:2004, **1.2.2** applies.

1.2.4 Additional general and other reference standards for bridges

EN 1990: Annex A2 Basis of structural design: Application for bridges

EN 1991-2:2003 Actions on structures: Traffic loads on bridges

EN 1992-2:2005 Design of concrete structures. Part 2 – Bridges

EN 1993-2:2005 Design of steel structures. Part 2 – Bridges

EN 1994-2:2005 Design of composite (steel-concrete) structures. Part 2 – Bridges

EN 1998-1:2004 Design of structures for earthquake resistance. General rules, seismic actions and rules for buildings

EN 1998-5:2004 Design of structures for earthquake resistance. Foundations, retaining structures and geotechnical aspects.

EN 1337-2:2000 Structural bearings – Part 2: Sliding elements

EN 1337-3:2005 Structural bearings – Part 3: Elastomeric bearings

prEN 15129:200X Antiseismic Devices

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 of 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 of members.

1.4 Distinction between principles and application rules

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

1.5 Definitions

1.5.1 General

(1) For the purposes of this standard the following definitions are applicable.

1.5.2 Terms common to all Eurocodes

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

1.5.3 Further terms used in EN 1998-2

capacity design
design procedure used when designing structures of ductile behaviour to ensure the hierarchy of strengths of the various structural components necessary for leading to the intended configuration of plastic hinges and for avoiding brittle failure modes

ductile members
members able to dissipate energy through the formation of plastic hinges

ductile structure
structure that under strong seismic motions can dissipate significant amounts of input energy through the formation of an intended configuration of plastic hinges or by other mechanisms

limited ductile behaviour
seismic behaviour of bridges, without significant dissipation of energy in plastic hinges under the design seismic action

positive linkage
connection implemented by seismic links

seismic isolation
provision of bridge structures with special isolating devices for the purpose of reducing the seismic response (forces and/or displacements)

spatial variability (of seismic action)
situation in which the ground motion at different supports of the bridge differs and, hence, the seismic action cannot be based on the characterisation of the motion at a single point

seismic behaviour
behaviour of the bridge under the design seismic event which, depending on the characteristics of the global force-displacement relationship of the structure, can be ductile or limited ductile/essentially elastic

seismic links
restrainers through which part or all of the seismic action may be transmitted. Used in combination with bearings, they may be provided with appropriate slack, so as to be activated only in the case when the design seismic displacement is exceeded

minimum overlap length
safety measure in the form of a minimum distance between the inner edge of the supported and the outer edge of the supporting member. The minimum overlap is intended to ensure that the function of the support is maintained under extreme seismic displacements

design seismic displacement
displacement induced by the design seismic actions.

total design displacement in the seismic design situation
displacement used to determine adequate clearances for the protection of critical or major structural members. It includes the design seismic displacement, the displacement due to the long term effect of the permanent and quasi-permanent actions and an appropriate fraction of the displacement due to thermal movements.

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 the seismic actions, are defined in the text where they occur, for ease of use. However, in addition, the most frequently occurring symbols in EN 1998-2 are listed and defined in the following subsections.

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

d_E design seismic displacement (due only to the design seismic action)

d_{Ee} seismic displacement determined from linear analysis

d_G long term displacement due to the permanent and quasi-permanent actions

d_g design ground displacement in accordance with EN 1998-1:2004, **3.2.2.4**

d_i ground displacement of set B at support i

d_{ri} ground displacement at support i relative to reference support 0

d_T displacement due to thermal movements

d_u ultimate displacement

d_y yield displacement

A_{Ed} design seismic action

F_{Rd} design value of resisting force to the earthquake action

L_g distance beyond which the ground motion may be considered completely uncorrelated

L_i distance of support i from reference support 0

$L_{i-1,i}$ distance between consecutive supports i-1 and i

R_i reaction force at the base of pier i

S_a site-averaged response spectrum

S_i site-dependent response spectrum

T_{eff} effective period of the isolation system

γ_I importance factor

Δd_i ground displacement of intermediate support i relative to adjacent supports i-1 and i+1

μ_d displacement ductility factor

ψ_2 combination factor for the quasi-permanent value of thermal action