

**SS EN 1998-1:2013(2021)+A1:2021**  
**EN 1998-1:2004+A1:2013, IDT**  
(ICS 91.120.25)

**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

**SS EN 1998-1:2013(2021)+A1:2021**  
EN 1998-1:2004+A1:2013, IDT  
(ICS 91.120.25)

---

SINGAPORE STANDARD

**Eurocode 8 : Design of structures for earthquake  
resistance**

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

---

Published by Enterprise Singapore

All rights reserved. Unless otherwise specified, no part of this publication may be reproduced or utilised in any form or by any means, electronic or mechanical, including photocopying and microfilming, without permission in writing from Enterprise Singapore. Request for permission can be sent to: [standards@enterprisesg.gov.sg](mailto:standards@enterprisesg.gov.sg).

© CEN 2004  
© Enterprise Singapore 2013

ISBN 978-981-5024-60-9

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

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

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.

**NOTE**

- 1. Singapore Standards (SSs) and Technical References (TRs) are reviewed periodically to keep abreast of technical changes, technological developments and industry practices. The changes are documented through the issue of either amendments or revisions. Where SSs are deemed to be stable, i.e. no foreseeable changes in them, they will be classified as “Mature Standards”. Mature Standards will not be subject to further review, unless there are requests to review such standards.*
- 2. An SS or TR is voluntary in nature except when it is made mandatory by a regulatory authority. It can also be cited in contracts making its application a business necessity. Users are advised to assess and determine whether the SS or TR is suitable for their intended use or purpose. If required, they should refer to the relevant professionals or experts for advice on the use of the document. Enterprise Singapore and the Singapore Standards Council shall not be liable for any damages whether directly or indirectly suffered by anyone or any organisation as a result of the use of any SS or TR. Although care has been taken to draft this standard, users are also advised to ensure that they apply the information after due diligence.*
- 3. Compliance with a SS or TR does not exempt users from any legal obligations.*

EUROPEAN STANDARD

**EN 1998-1**

NORME EUROPÉENNE

EUROPÄISCHE NORM

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.



EUROPEAN COMMITTEE FOR STANDARDIZATION  
COMITÉ EUROPÉEN DE NORMALISATION  
EUROPÄISCHES KOMITEE FÜR NORMUNG

**Management Centre: rue de Stassart, 36 B-1050 Brussels**

**EN 1998-1:2004 (E)**

<b>Contents</b>	<b>Page</b>
<b>FOREWORD.....</b>	<b>8</b>
<b>1 GENERAL.....</b>	<b>15</b>
1.1 SCOPE .....	15
1.1.1 Scope of EN 1998.....	15
1.1.2 Scope of EN 1998-1 .....	15
1.1.3 Further Parts of EN 1998.....	16
1.2 NORMATIVE REFERENCES.....	16
1.2.1 General reference standards.....	16
1.2.2 Reference Codes and Standards.....	17
1.3 ASSUMPTIONS .....	17
1.4 DISTINCTION BETWEEN PRINCIPLES AND APPLICATION RULES .....	17
1.5 TERMS AND DEFINITIONS .....	17
1.5.1 Terms common to all Eurocodes.....	17
1.5.2 Further terms used in EN 1998.....	17
1.6 SYMBOLS .....	19
1.6.1 General .....	19
1.6.2 Further symbols used in Sections 2 and 3 of EN 1998-1.....	19
1.6.3 Further symbols used in Section 4 of EN 1998-1.....	20
1.6.4 Further symbols used in Section 5 of EN 1998-1.....	21
1.6.5 Further symbols used in Section 6 of EN 1998-1.....	24
1.6.6 Further symbols used in Section 7 of EN 1998-1.....	25
1.6.7 Further symbols used in Section 8 of EN 1998-1.....	27
1.6.8 Further symbols used in Section 9 of EN 1998-1.....	27
1.6.9 Further symbols used in Section 10 of EN 1998-1.....	28
1.7 S.I. UNITS .....	28
<b>2 PERFORMANCE REQUIREMENTS AND COMPLIANCE CRITERIA .....</b>	<b>29</b>
2.1 FUNDAMENTAL REQUIREMENTS.....	29
2.2 COMPLIANCE CRITERIA.....	30
2.2.1 General .....	30
2.2.2 Ultimate limit state .....	30
2.2.3 Damage limitation state.....	31
2.2.4 Specific measures .....	32
2.2.4.1 Design .....	32
2.2.4.2 Foundations.....	32
2.2.4.3 Quality system plan.....	32
<b>3 GROUND CONDITIONS AND SEISMIC ACTION.....</b>	<b>33</b>
3.1 GROUND CONDITIONS .....	33
3.1.2 Identification of ground types.....	33
3.2 SEISMIC ACTION.....	35
3.2.1 Seismic zones .....	35
3.2.2 Basic representation of the seismic action.....	36
3.2.2.1 General.....	36
3.2.2.2 Horizontal elastic response spectrum.....	37
3.2.2.3 Vertical elastic response spectrum .....	40
3.2.2.4 Design ground displacement .....	41
3.2.2.5 Design spectrum for elastic analysis.....	41
3.2.3 Alternative representations of the seismic action .....	42
3.2.3.1 Time - history representation .....	42
3.2.3.2 Spatial model of the seismic action.....	43
3.2.4 Combinations of the seismic action with other actions.....	44
<b>4 DESIGN OF BUILDINGS .....</b>	<b>45</b>
4.1 GENERAL .....	45

4.1.1	Scope .....	45
4.2	CHARACTERISTICS OF EARTHQUAKE RESISTANT BUILDINGS .....	45
4.2.1	Basic principles of conceptual design.....	45
4.2.1.1	Structural simplicity .....	45
4.2.1.2	Uniformity, symmetry and redundancy.....	45
4.2.1.3	Bi-directional resistance and stiffness .....	46
4.2.1.4	Torsional resistance and stiffness.....	46
4.2.1.5	Diaphragmatic behaviour at storey level .....	46
4.2.1.6	Adequate foundation .....	47
4.2.2	Primary and secondary seismic members .....	47
4.2.3	Criteria for structural regularity .....	48
4.2.3.1	General.....	48
4.2.3.2	Criteria for regularity in plan.....	49
4.2.3.3	Criteria for regularity in elevation.....	50
4.2.4	Combination coefficients for variable actions .....	52
4.2.5	Importance classes and importance factors .....	52
4.3	STRUCTURAL ANALYSIS .....	53
4.3.1	Modelling .....	53
4.3.2	Accidental torsional effects .....	54
4.3.3	Methods of analysis .....	54
4.3.3.1	General.....	54
4.3.3.2	Lateral force method of analysis .....	56
4.3.3.3	Modal response spectrum analysis .....	59
4.3.3.4	Non-linear methods.....	61
4.3.3.5	Combination of the effects of the components of the seismic action .....	64
4.3.4	Displacement calculation.....	66
4.3.5	Non-structural elements.....	66
4.3.5.1	General.....	66
4.3.5.2	Verification .....	67
4.3.5.3	Importance factors.....	68
4.3.5.4	Behaviour factors .....	68
4.3.6	Additional measures for masonry infilled frames.....	68
4.3.6.1	General.....	68
4.3.6.2	Requirements and criteria.....	69
4.3.6.3	Irregularities due to masonry infills .....	69
4.3.6.4	Damage limitation of infills .....	70
4.4	SAFETY VERIFICATIONS .....	71
4.4.1	General .....	71
4.4.2	Ultimate limit state .....	71
4.4.2.1	General.....	71
4.4.2.2	Resistance condition.....	71
4.4.2.3	Global and local ductility condition .....	72
4.4.2.4	Equilibrium condition .....	74
4.4.2.5	Resistance of horizontal diaphragms.....	74
4.4.2.6	Resistance of foundations.....	74
4.4.2.7	Seismic joint condition.....	75
4.4.3	Damage limitation .....	76
4.4.3.1	General.....	76
4.4.3.2	Limitation of interstorey drift.....	76
<b>5</b>	<b>SPECIFIC RULES FOR CONCRETE BUILDINGS .....</b>	<b>78</b>
5.1	GENERAL .....	78
5.1.1	Scope .....	78
5.1.2	Terms and definitions .....	78
5.2	DESIGN CONCEPTS .....	80
5.2.1	Energy dissipation capacity and ductility classes .....	80
5.2.2	Structural types and behaviour factors.....	81
5.2.2.1	Structural types .....	81
5.2.2.2	Behaviour factors for horizontal seismic actions.....	82
5.2.3	Design criteria .....	84
5.2.3.1	General.....	84
5.2.3.2	Local resistance condition.....	84
5.2.3.3	Capacity design rule.....	84
5.2.3.4	Local ductility condition .....	84

**EN 1998-1:2004 (E)**

5.2.3.5	Structural redundancy .....	86
5.2.3.6	Secondary seismic members and resistances .....	86
5.2.3.7	Specific additional measures .....	86
5.2.4	Safety verifications .....	87
5.3	DESIGN TO EN 1992-1-1 .....	87
5.3.1	General .....	87
5.3.2	Materials .....	88
5.3.3	Behaviour factor .....	88
5.4	DESIGN FOR DCM .....	88
5.4.1	Geometrical constraints and materials .....	88
5.4.1.1	Material requirements .....	88
5.4.1.2	Geometrical constraints .....	88
5.4.2	Design action effects .....	89
5.4.2.1	General .....	89
5.4.2.2	Beams .....	89
5.4.2.3	Columns .....	91
5.4.2.4	Special provisions for ductile walls .....	92
5.4.2.5	Special provisions for large lightly reinforced walls .....	94
5.4.3	ULS verifications and detailing .....	95
5.4.3.1	Beams .....	95
5.4.3.2	Columns .....	97
5.4.3.3	Beam-column joints .....	100
5.4.3.4	Ductile Walls .....	100
5.4.3.5	Large lightly reinforced walls .....	104
5.5	DESIGN FOR DCH .....	106
5.5.1	Geometrical constraints and materials .....	106
5.5.1.1	Material requirements .....	106
5.5.1.2	Geometrical constraints .....	106
5.5.2	Design action effects .....	107
5.5.2.1	Beams .....	107
5.5.2.2	Columns .....	107
5.5.2.3	Beam-column joints .....	107
5.5.2.4	Ductile Walls .....	108
5.5.3	ULS verifications and detailing .....	109
5.5.3.1	Beams .....	109
5.5.3.2	Columns .....	111
5.5.3.3	Beam-column joints .....	112
5.5.3.4	Ductile Walls .....	114
5.5.3.5	Coupling elements of coupled walls .....	119
5.6	PROVISIONS FOR ANCHORAGES AND SPLICES .....	120
5.6.1	General .....	120
5.6.2	Anchorage of reinforcement .....	120
5.6.2.1	Columns .....	120
5.6.2.2	Beams .....	120
5.6.3	Splicing of bars .....	122
5.7	DESIGN AND DETAILING OF SECONDARY SEISMIC ELEMENTS .....	123
5.8	CONCRETE FOUNDATION ELEMENTS .....	123
5.8.1	Scope .....	123
5.8.2	Tie-beams and foundation beams .....	124
5.8.3	Connections of vertical elements with foundation beams or walls .....	125
5.8.4	Cast-in-place concrete piles and pile caps .....	125
5.9	LOCAL EFFECTS DUE TO MASONRY OR CONCRETE INFILLS .....	126
5.10	PROVISIONS FOR CONCRETE DIAPHRAGMS .....	127
5.11	PRECAST CONCRETE STRUCTURES .....	127
5.11.1	General .....	127
5.11.1.1	Scope and structural types .....	127
5.11.1.2	Evaluation of precast structures .....	128
5.11.1.3	Design criteria .....	129
5.11.1.4	Behaviour factors .....	130
5.11.1.5	Analysis of transient situation .....	130
5.11.2	Connections of precast elements .....	131
5.11.2.1	General provisions .....	131
5.11.2.2	Evaluation of the resistance of connections .....	132
5.11.3	Elements .....	132



5.11.3.1	Beams.....	132
5.11.3.2	Columns.....	132
5.11.3.3	Beam-column joints.....	133
5.11.3.4	Precast large-panel walls.....	133
5.11.3.5	Diaphragms.....	135
<b>6</b>	<b>SPECIFIC RULES FOR STEEL BUILDINGS.....</b>	<b>137</b>
6.1	GENERAL.....	137
6.1.1	Scope.....	137
6.1.2	Design concepts.....	137
6.1.3	Safety verifications.....	138
6.2	MATERIALS.....	138
6.3	STRUCTURAL TYPES AND BEHAVIOUR FACTORS.....	140
6.3.1	Structural types.....	140
6.3.2	Behaviour factors.....	143
6.4	STRUCTURAL ANALYSIS.....	144
6.5	DESIGN CRITERIA AND DETAILING RULES FOR DISSIPATIVE STRUCTURAL BEHAVIOUR COMMON TO ALL STRUCTURAL TYPES.....	144
6.5.1	General.....	144
6.5.2	Design criteria for dissipative structures.....	144
6.5.3	Design rules for dissipative elements in compression or bending.....	145
6.5.4	Design rules for parts or elements in tension.....	145
6.5.5	Design rules for connections in dissipative zones.....	145
6.6	DESIGN AND DETAILING RULES FOR MOMENT RESISTING FRAMES.....	146
6.6.1	Design criteria.....	146
6.6.2	Beams.....	146
6.6.3	Columns.....	147
6.6.4	Beam to column connections.....	149
6.7	DESIGN AND DETAILING RULES FOR FRAMES WITH CONCENTRIC BRACINGS.....	150
6.7.1	Design criteria.....	150
6.7.2	Analysis.....	151
6.7.3	Diagonal members.....	152
6.7.4	Beams and columns.....	152
6.8	DESIGN AND DETAILING RULES FOR FRAMES WITH ECCENTRIC BRACINGS.....	153
6.8.1	Design criteria.....	153
6.8.2	Seismic links.....	154
6.8.3	Members not containing seismic links.....	157
6.8.4	Connections of the seismic links.....	158
6.9	DESIGN RULES FOR INVERTED PENDULUM STRUCTURES.....	158
6.10	DESIGN RULES FOR STEEL STRUCTURES WITH CONCRETE CORES OR CONCRETE WALLS AND FOR MOMENT RESISTING FRAMES COMBINED WITH CONCENTRIC BRACINGS OR INFILLS.....	159
6.10.1	Structures with concrete cores or concrete walls.....	159
6.10.2	Moment resisting frames combined with concentric bracings.....	159
6.10.3	Moment resisting frames combined with infills.....	159
6.11	CONTROL OF DESIGN AND CONSTRUCTION.....	159
<b>7</b>	<b>SPECIFIC RULES FOR COMPOSITE STEEL – CONCRETE BUILDINGS.....</b>	<b>161</b>
7.1	GENERAL.....	161
7.1.1	Scope.....	161
7.1.2	Design concepts.....	161
7.1.3	Safety verifications.....	162
7.2	MATERIALS.....	163
7.2.1	Concrete.....	163
7.2.2	Reinforcing steel.....	163
7.2.3	Structural steel.....	163
7.3	STRUCTURAL TYPES AND BEHAVIOUR FACTORS.....	163
7.3.1	Structural types.....	163
7.3.2	Behaviour factors.....	165
7.4	STRUCTURAL ANALYSIS.....	165
7.4.1	Scope.....	165
7.4.2	Stiffness of sections.....	166

**EN 1998-1:2004 (E)**

7.5	DESIGN CRITERIA AND DETAILING RULES FOR DISSIPATIVE STRUCTURAL BEHAVIOUR COMMON TO ALL STRUCTURAL TYPES.....	166
7.5.1	General .....	166
7.5.2	Design criteria for dissipative structures .....	166
7.5.3	Plastic resistance of dissipative zones .....	167
7.5.4	Detailing rules for composite connections in dissipative zones.....	167
7.6	RULES FOR MEMBERS .....	170
7.6.1	General .....	170
7.6.2	Steel beams composite with slab .....	172
7.6.3	Effective width of slab.....	174
7.6.4	Fully encased composite columns .....	176
7.6.5	Partially-encased members .....	178
7.6.6	Filled Composite Columns .....	179
7.7	DESIGN AND DETAILING RULES FOR MOMENT FRAMES.....	179
7.7.1	Specific criteria.....	179
7.7.2	Analysis.....	180
7.7.3	Rules for beams and columns.....	180
7.7.4	Beam to column connections.....	181
7.7.5	Condition for disregarding the composite character of beams with slab.....	181
7.8	DESIGN AND DETAILING RULES FOR COMPOSITE CONCENTRICALLY BRACED FRAMES.....	181
7.8.1	Specific criteria.....	181
7.8.2	Analysis.....	181
7.8.3	Diagonal members.....	181
7.8.4	Beams and columns.....	181
7.9	DESIGN AND DETAILING RULES FOR COMPOSITE ECCENTRICALLY BRACED FRAMES .....	181
7.9.1	Specific criteria.....	181
7.9.2	Analysis.....	182
7.9.3	Links.....	182
7.9.4	Members not containing seismic links.....	183
7.10	DESIGN AND DETAILING RULES FOR STRUCTURAL SYSTEMS MADE OF REINFORCED CONCRETE SHEAR WALLS COMPOSITE WITH STRUCTURAL STEEL ELEMENTS.....	183
7.10.1	Specific criteria.....	183
7.10.2	Analysis.....	185
7.10.3	Detailing rules for composite walls of ductility class DCM.....	185
7.10.4	Detailing rules for coupling beams of ductility class DCM.....	186
7.10.5	Additional detailing rules for ductility class DCH.....	186
7.11	DESIGN AND DETAILING RULES FOR COMPOSITE STEEL PLATE SHEAR WALLS .....	186
7.11.1	Specific criteria.....	186
7.11.2	Analysis.....	187
7.11.3	Detailing rules.....	187
7.12	CONTROL OF DESIGN AND CONSTRUCTION .....	187
<b>8</b>	<b>SPECIFIC RULES FOR TIMBER BUILDINGS.....</b>	<b>188</b>
8.1	GENERAL .....	188
8.1.1	Scope .....	188
8.1.2	Definitions .....	188
8.1.3	Design concepts.....	188
8.2	MATERIALS AND PROPERTIES OF DISSIPATIVE ZONES.....	189
8.3	DUCTILITY CLASSES AND BEHAVIOUR FACTORS.....	190
8.4	STRUCTURAL ANALYSIS .....	191
8.5	DETAILING RULES .....	191
8.5.1	General .....	191
8.5.2	Detailing rules for connections.....	192
8.5.3	Detailing rules for horizontal diaphragms .....	192
8.6	SAFETY VERIFICATIONS .....	192
8.7	CONTROL OF DESIGN AND CONSTRUCTION .....	193
<b>9</b>	<b>SPECIFIC RULES FOR MASONRY BUILDINGS .....</b>	<b>194</b>
9.1	SCOPE .....	194
9.2	MATERIALS AND BONDING PATTERNS .....	194

9.2.1	Types of masonry units.....	194
9.2.2	Minimum strength of masonry units.....	194
9.2.3	Mortar.....	194
9.2.4	Masonry bond.....	194
9.3	TYPES OF CONSTRUCTION AND BEHAVIOUR FACTORS.....	195
9.4	STRUCTURAL ANALYSIS.....	196
9.5	DESIGN CRITERIA AND CONSTRUCTION RULES.....	197
9.5.1	General.....	197
9.5.2	Additional requirements for unreinforced masonry satisfying EN 1998-1.....	198
9.5.3	Additional requirements for confined masonry.....	198
9.5.4	Additional requirements for reinforced masonry.....	199
9.6	SAFETY VERIFICATION.....	200
9.7	RULES FOR “SIMPLE MASONRY BUILDINGS”.....	200
9.7.1	General.....	200
9.7.2	Rules.....	200
<b>10</b>	<b>BASE ISOLATION.....</b>	<b>203</b>
10.1	SCOPE.....	203
10.2	DEFINITIONS.....	203
10.3	FUNDAMENTAL REQUIREMENTS.....	204
10.4	COMPLIANCE CRITERIA.....	205
10.5	GENERAL DESIGN PROVISIONS.....	205
10.5.1	General provisions concerning the devices.....	205
10.5.2	Control of undesirable movements.....	206
10.5.3	Control of differential seismic ground motions.....	206
10.5.4	Control of displacements relative to surrounding ground and constructions.....	206
10.5.5	Conceptual design of base isolated buildings.....	206
10.6	SEISMIC ACTION.....	207
10.7	BEHAVIOUR FACTOR.....	207
10.8	PROPERTIES OF THE ISOLATION SYSTEM.....	207
10.9	STRUCTURAL ANALYSIS.....	208
10.9.1	General.....	208
10.9.2	Equivalent linear analysis.....	208
10.9.3	Simplified linear analysis.....	209
10.9.4	Modal simplified linear analysis.....	211
10.9.5	Time-history analysis.....	211
10.9.6	Non structural elements.....	211
10.10	SAFETY VERIFICATIONS AT ULTIMATE LIMIT STATE.....	211
	<b>ANNEX A (INFORMATIVE) ELASTIC DISPLACEMENT RESPONSE SPECTRUM.....</b>	<b>213</b>
	<b>ANNEX B (INFORMATIVE) DETERMINATION OF THE TARGET DISPLACEMENT FOR NONLINEAR STATIC (PUSHOVER) ANALYSIS.....</b>	<b>215</b>
	<b>ANNEX C (NORMATIVE) DESIGN OF THE SLAB OF STEEL-CONCRETE COMPOSITE BEAMS AT BEAM-COLUMN JOINTS IN MOMENT RESISTING FRAMES.....</b>	<b>219</b>

**EN 1998-1:2004 (E)****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<sup>1</sup> 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).

---

<sup>1</sup> 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<sup>2</sup> referred to in Article 12 of the CPD, although they are of a different nature from harmonised product standards<sup>3</sup>. Therefore, technical aspects arising from the Eurocodes work need to be adequately considered by

---

<sup>2</sup> 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.

<sup>3</sup> 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.

**EN 1998-1:2004 (E)**

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<sup>4</sup>. 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**.

---

<sup>4</sup> 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 <b>3.2.2.2</b> and <b>3.2.2.3</b> .
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 .

## EN 1998-1:2004 (E)

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 $\beta$ 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 <b>4.2.3.2(8)</b>
4.2.4(2)P	Values of $\varphi$ for buildings.
4.2.5(5)P	Importance factor $\gamma_I$ 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, $\gamma_I$ , relating to the permitted use of analysis with two planar models.
4.4.2.5 (2).	Overstrength factor $\gamma_{Rd}$ for diaphragms.
4.4.3.2 (2)	Reduction factor $\nu$ 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.

**EN 1998-1:2004 (E)**

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:

### **EN 1998-1:2004 (E)**

- 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:

**EN 1998-1:2004 (E)**

**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 ( $= \gamma_1 A_{Ek}$ )
$A_{Ek}$	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

**EN 1998-1:2004 (E)**

$v_{s,30}$	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
$\gamma$	importance factor
$\eta$	damping correction factor
$\xi$	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
$\alpha$	ratio of the design ground acceleration to the acceleration of gravity



$\gamma_a$	importance factor of a non-structural element (appendage)
$\gamma_d$	overstrength factor for diaphragms
$\theta$	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
$\Sigma A_{si}$	sum of areas of all inclined bars in both directions, in wall reinforced with inclined bars against sliding shear
$\Sigma A_{sj}$	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
$\Sigma M_{Rb}$	sum of design values of moments of resistance of the beams framing into a joint in the direction of interest
$\Sigma M_{Rc}$	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

**EN 1998-1:2004 (E)**

$V_{Rd,c}$	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
$\alpha$	confinement effectiveness factor, angle between diagonal bars and axis of a coupling beam
$\alpha_o$	prevailing aspect ratio of walls of the structural system
$\alpha_1$	multiplier of horizontal design seismic action at formation of first plastic hinge in the system
$\alpha_u$	multiplier of horizontal seismic design action at formation of global plastic mechanism
$\gamma_c$	partial factor for concrete
$\gamma_{Rd}$	model uncertainty factor on design value of resistances in the estimation of capacity design action effects, accounting for various sources of overstrength
$\gamma_s$	partial factor for steel
$\varepsilon_{cu2}$	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
$\eta$	reduction factor on concrete compressive strength due to tensile strains in transverse direction
$\zeta$	ratio, $V_{Ed,min}/V_{Ed,max}$ , between the minimum and maximum acting shear forces at the end section of a beam
$\mu_f$	concrete-to-concrete friction coefficient under cyclic actions
$\mu_\phi$	curvature ductility factor
$\mu_\delta$	displacement ductility factor
$\nu$	axial force due in the seismic design situation, normalised to $A_c f_{cd}$
$\xi$	normalised neutral axis depth
$\rho$	tension reinforcement ratio
$\rho'$	compression steel ratio in beams
$\sigma_{cm}$	mean value of concrete normal stress

**EN 1998-1:2004 (E)**

$\rho_h$	reinforcement ratio of horizontal web bars in a wall
$\rho_l$	total longitudinal reinforcement ratio
$\rho_{\max}$	maximum allowed tension steel ratio in the critical region of primary seismic beams
$\rho_v$	reinforcement ratio of vertical web bars in a wall
$\rho_w$	shear reinforcement ratio
$\omega_v$	mechanical ratio of vertical web reinforcement
$\omega_{wd}$	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
$\Omega$	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
$\alpha$	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
$\alpha_1$	multiplier of horizontal design seismic action at formation of first plastic hinge in the system
$\alpha_u$	multiplier of horizontal seismic design action at formation of global plastic mechanism
$\gamma_M$	partial factor for material property
$\gamma_{ov}$	material overstrength factor
$\delta$	beam deflection at midspan relative to tangent to beam axis at beam end (see Figure 6.11)
$\gamma_{pb}$	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
$\gamma_s$	partial factor for steel
$\theta_p$	rotation capacity of the plastic hinge region
$\bar{\lambda}$	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

**EN 1998-1:2004 (E)**

$M_{U,Rd,b}$	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
$\gamma_c$	partial factor for concrete
$\gamma_M$	partial factor for material property
$\gamma_{ov}$	material overstrength factor
$\gamma_s$	partial factor for steel
$\varepsilon_a$	total strain of steel at Ultimate Limit State
$\varepsilon_{cu2}$	ultimate compressive strain of unconfined concrete
$\eta$	minimum degree of connection as defined in <b>6.6.1.2</b> 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
$\gamma_M$	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”
$\gamma_m$	partial factors for masonry properties
$\gamma_s$	partial factor for reinforcing steel
$\lambda_{min}$	ratio between the length of the small and the length of the long side in plan

**EN 1998-1:2004 (E)****1.6.9 Further symbols used in Section 10 of EN 1998-1**

$K_{\text{eff}}$	effective stiffness of the isolation system in the principal horizontal direction under consideration, at a displacement equal to the design displacement $d_{\text{dc}}$
$K_{\text{V}}$	total stiffness of the isolation system in the vertical direction
$K_{\text{xi}}$	effective stiffness of a given unit $i$ in the $x$ direction
$K_{\text{yi}}$	effective stiffness of a given unit $i$ in the $y$ direction
$T_{\text{eff}}$	effective fundamental period of the superstructure corresponding to horizontal translation, the superstructure assumed as a rigid body
$T_{\text{f}}$	fundamental period of the superstructure assumed fixed at the base
$T_{\text{V}}$	fundamental period of the superstructure in the vertical direction, the superstructure assumed as a rigid body
$M$	mass of the superstructure
$M_{\text{s}}$	magnitude
$d_{\text{dc}}$	design displacement of the effective stiffness centre in the direction considered
$d_{\text{db}}$	total design displacement of an isolator unit
$e_{\text{tot,y}}$	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
$\delta_i$	amplification factor
$\xi_{\text{eff}}$	“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<sup>2</sup>
- unit mass: kg/m<sup>3</sup>, t/m<sup>3</sup>
- mass: kg, t
- unit weight: kN/m<sup>3</sup>
- stresses and strengths: N/mm<sup>2</sup> (= MN/m<sup>2</sup> or MPa), kN/m<sup>2</sup> (=kPa)
- moments (bending, etc): kNm
- acceleration: m/s<sup>2</sup>, g (=9,81 m/s<sup>2</sup>)