

SINGAPORE STANDARD

Eurocode 4 - Design of composite steel and concrete structures

**– Part 1-1 : General rules and rules for
buildings**

(This national standard is the identical implementation of EN 1994-1-1 : 2004 and is adopted with permission of CEN, Avenue Marnix 17, 1000 Brussels)

Published by

Enterprise
Singapore

SS EN 1994-1-1 : 2009

EN 1994-1-1 : 2004, IDT

(ICS 91.010.30; 91.080.10; 91.080.40)

SINGAPORE STANDARD

**Eurocode 4 - Design of composite steel and
concrete structures**

– Part 1-1 : General rules and rules for buildings

All rights reserved. Unless otherwise specified, no part of this Singapore Standard 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.

ISBN 978-981-4278-20-1

This Singapore Standard was approved by the Building and Construction Standards Committee on behalf of the Standards Council of Singapore on 6 October 2009.

First published, 2009

The Building and Construction Standards Committee appointed by the Standards Council consists of the following members:

| | Name | Capacity |
|-----------------------------------|-------------------------------|--|
| Chairman | : Mr Goh Peng Thong | <i>Member, Standards Council</i> |
| 1st Dy Chairman | : Mr Lee Chuan Seng | <i>Member, Standards Council</i> |
| 2nd Dy Chairman | : Mr Tan Tian Chong | <i>Member, Standards Council</i> |
| Secretary | : Mr James Choo Sou Yong | <i>SPRING Singapore</i> |
| Members | : Mr Boo Geok Kwang | <i>Singapore Civil Defence Force</i> |
| | Er. Chan Ewe Jin | <i>Institution of Engineers, Singapore</i> |
| | Mr Chan Yew Kwong | <i>Ministry of Manpower</i> |
| | Mr Paul Fok | <i>Land Transport Authority</i> |
| | Mr Goh Ngan Hong | <i>Singapore Institute of Surveyors and Valuers</i> |
| | Mr Anselm Gonsalves | <i>National Environment Agency</i> |
| | Mr Desmond Hill | <i>Singapore Contractors Association Limited</i> |
| | Mr Benedict Lee Khee Chong | <i>Singapore Institute of Architects</i> |
| | Ms Andris Leong | <i>Building and Construction Authority</i> |
| | Assoc Prof Leong Eng Choon | <i>Nanyang Technological University</i> |
| | Dr Lim Lan-Yuan | <i>The Association of Property and Facility Managers</i> |
| | Mr McDonald Low | <i>Real Estate Developers' Association of Singapore</i> |
| | Mr Larry Ng Lye Hock | <i>Urban Redevelopment Authority</i> |
| | Assoc Prof Gary Ong Khim Chye | <i>National University of Singapore</i> |
| | Mr Davis Ong Wee Choon | <i>Singapore Manufacturers' Federation</i> |
| | Er. Shum Chee Hoong | <i>Housing & Development Board</i> |
| | Dr Tan Guan | <i>Association of Consulting Engineers, Singapore</i> |
| | Mr Tang Pei Luen | <i>JTC Corporation</i> |
| Co-opted Members | : Prof Choo Yoo Sang | <i>National University of Singapore</i> |
| | Dr Tam Chat Tim | <i>Individual Capacity</i> |

The Technical Committee on Building Structure and Sub-structure appointed by the Building and Construction Standards Committee and responsible for the preparation of this standard consists of representatives from the following organisations:

| | Name | Capacity |
|-------------------------|-------------------------------|--|
| Chairman | : Dr Tan Guan | <i>Member, Building and Construction Standards Committee</i> |
| Co-Chairman | : Er. Chew Keat Chuan | <i>Building and Construction Authority</i> |
| Secretary | : Ms Lee Hiok Hoong | <i>SPRING Singapore</i> |
| Members | : Er. Chan Ewe Jin | <i>Institution of Engineers, Singapore</i> |
| | Dr Chen Enyi | <i>Cement and Concrete Association of Singapore</i> |
| | LTC Cheok Poh Chin | <i>Singapore Civil Defence Force</i> |
| | Dr Sujit Ghosh | <i>Ready Mix Concrete Association of Singapore</i> |
| | Dr Ho Nyok Yong | <i>Singapore Contractors Association Ltd</i> |
| | Mr Ho Wan Boon | <i>Singapore Structural Steel Society</i> |
| | Mdm Neo Bian Hong | <i>Land Transport Authority</i> |
| | Assoc Prof Gary Ong Khim Chye | <i>Singapore Concrete Institute</i> |
| | Mr Sze Thiam Siong | <i>Setsco Services Pte Ltd</i> |
| | Er. Angeline Tan Bee Hoon | <i>Housing & Development Board</i> |
| | Er. Tan Jui Teck | <i>CPG Corporation Pte Ltd</i> |
| | Assoc Prof Tan Kiang Hwee | <i>National University of Singapore</i> |
| | Er. Tang Pei Luen | <i>JTC Corporation</i> |
| | Assoc Prof Susanto Teng | <i>Nanyang Technological University</i> |
| Co-opted Members | : Dr Tam Chat Tim | <i>Individual Capacity</i> |
| | Dr Tan Teng Hooi | <i>Individual Capacity</i> |
| | Er. Tay Yak Hong | <i>Individual Capacity</i> |

The following Technical Experts contributed in their *individual capacity* to the preparation of this standard:

Prof Richard Liew Jat Yuen (Convenor / Taskforce Leader)
Mr Ho Wan Boon (Co-Convenor)
Er. Patrick Choy (Secretary)
Dr Chiew Sing-Ping
Mr Bernard Chung
Mr Melvin Soh
Er. Tay Yak Hong

The organisations in which the experts are involved are:

Building and Construction Authority
Continental Steel Pte Ltd
Corus South East Asia Pte Ltd
Nanyang Technological University
National University of Singapore
TYH Consulting Engineers
Yongnam Engineering & Construction Pte Ltd

National Foreword

This Singapore Standard was prepared by the Technical Committee on Building Structure and Sub-structure under the direction of the Building and Construction Standards Committee.

This SS EN is the identical implementation of 1994-1-1 : 2004 'Eurocode 4: Design of composite steel and concrete structures – Part 1-1: General rules and rules for buildings' including its Corrigendum EN 1994-1-1:2004/AC : 2009 (incorporated after the main text) and is adopted with permission of CEN, Rue de Stassart 36, B-1050 Brussels.

Attention is drawn to the following:

- The comma has been used throughout as a decimal marker whereas in Singapore Standards, it is a practice to use a full point on the baseline as the decimal marker.
- 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 1994-1-1 : 2009 are to be read in conjunction with the Singapore National Annex (NA) to SS EN 1994-1-1 : 2009 which contains information on the Singapore Nationally Determined Parameters and is published separately.

National choice is allowed in EN 1994-1-1 through the following clauses:

- | | |
|---------------|------------|
| - 2.4.1.1(1) | - 6.8.2(1) |
| - 2.4.1.2(5) | - 6.8.2(2) |
| - 2.4.1.2(6) | - 9.1.1(2) |
| - 2.4.1.2(7) | - 9.6(2) |
| - 3.1(4) | - 9.7.3(4) |
| - 3.5(2) | - 9.7.3(8) |
| - 6.4.3(1)(h) | - 9.7.3(9) |
| - 6.6.3.1(1) | - B.2.5(1) |
| - 6.6.3.1(3) | - B.3.6(5) |
| - 6.6.4.1(3) | |

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

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.
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 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.
3. Compliance with a SS or TR does not exempt users from any legal obligations.

English version

Eurocode 4: Design of composite steel and concrete structures - Part 1-1: General rules and rules for buildings

Eurocode 4: Calcul des structures mixtes acier-béton -
Partie 1-1: Règles générales et règles pour les bâtiments

Eurocode 4: Bemessung und Konstruktion von
Verbundtragwerken aus Stahl und Beton - Teil 1-1:
Allgemeine Bemessungsregeln und Anwendungsregeln für
den Hochbau

This European Standard was approved by CEN on 27 May 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

| Contents | Page |
|---|-------------|
| Foreword..... | 8 |
| Section 1 General..... | 12 |
| 1.1 Scope..... | 12 |
| 1.1.1 Scope of Eurocode 4..... | 12 |
| 1.1.2 Scope of Part 1.1 of Eurocode 4..... | 12 |
| 1.2 Normative references..... | 13 |
| 1.2.1 General reference standards..... | 13 |
| 1.2.2 Other reference standards..... | 13 |
| 1.3 Assumptions..... | 14 |
| 1.4 Distinction between principles and application rules..... | 14 |
| 1.5 Definitions..... | 14 |
| 1.5.1 General..... | 14 |
| 1.5.2 Additional terms and definitions used in this Standard..... | 14 |
| 1.6 Symbols..... | 15 |
| Section 2 Basis of design..... | 22 |
| 2.1 Requirements..... | 22 |
| 2.2 Principles of limit state design..... | 23 |
| 2.3 Basic variables..... | 23 |
| 2.3.1 Actions and environmental influences..... | 23 |
| 2.3.2 Material and product properties..... | 23 |
| 2.3.3 Classification of actions..... | 23 |
| 2.4 Verification by the partial factor method..... | 23 |
| 2.4.1 Design values..... | 23 |
| 2.4.1.1 Design values of actions..... | 23 |
| 2.4.1.2 Design values of material or product properties..... | 23 |
| 2.4.1.3 Design values of geometrical data..... | 24 |
| 2.4.1.4 Design resistances..... | 24 |
| 2.4.2 Combination of actions..... | 24 |
| 2.4.3 Verification of static equilibrium (EQU)..... | 24 |
| Section 3 Materials..... | 24 |
| 3.1 Concrete..... | 24 |
| 3.2 Reinforcing steel..... | 25 |
| 3.3 Structural steel..... | 25 |
| 3.4 Connecting devices..... | 25 |
| 3.4.1 General..... | 25 |
| 3.4.2 Headed stud shear connectors..... | 25 |
| 3.5 Profiled steel sheeting for composite slabs in buildings..... | 25 |
| Section 4 Durability..... | 25 |
| 4.1 General..... | 25 |
| 4.2 Profiled steel sheeting for composite slabs in buildings..... | 26 |

| | |
|--|-----------|
| Section 5 Structural analysis..... | 26 |
| 5.1 Structural modelling for analysis..... | 26 |
| 5.1.1 Structural modelling and basic assumptions..... | 26 |
| 5.1.2 Joint modelling..... | 26 |
| 5.1.3 Ground-structure interaction..... | 26 |
| 5.2 Structural stability..... | 27 |
| 5.2.1 Effects of deformed geometry of the structure..... | 27 |
| 5.2.2 Methods of analysis for buildings..... | 27 |
| 5.3 Imperfections..... | 28 |
| 5.3.1 Basis..... | 28 |
| 5.3.2 Imperfections in buildings..... | 28 |
| 5.3.2.1 General..... | 28 |
| 5.3.2.2 Global imperfections..... | 29 |
| 5.3.2.3 Member imperfections..... | 29 |
| 5.4 Calculation of action effects..... | 29 |
| 5.4.1 Methods of global analysis..... | 29 |
| 5.4.1.1 General..... | 29 |
| 5.4.1.2 Effective width of flanges for shear lag..... | 29 |
| 5.4.2 Linear elastic analysis..... | 30 |
| 5.4.2.1 General..... | 30 |
| 5.4.2.2 Creep and shrinkage..... | 31 |
| 5.4.2.3 Effects of cracking of concrete..... | 32 |
| 5.4.2.4 Stages and sequence of construction..... | 33 |
| 5.4.2.5 Temperature effects..... | 33 |
| 5.4.2.6 Pre-stressing by controlled imposed deformations..... | 33 |
| 5.4.3 Non-linear global analysis..... | 33 |
| 5.4.4 Linear elastic analysis with limited redistribution for buildings..... | 34 |
| 5.4.5 Rigid plastic global analysis for buildings..... | 35 |
| 5.5 Classification of cross-sections..... | 36 |
| 5.5.1 General..... | 36 |
| 5.5.2 Classification of composite sections without concrete encasement..... | 37 |
| 5.5.3 Classification of composite sections for buildings with concrete encasement..... | 37 |
| Section 6 Ultimate limit states..... | 38 |
| 6.1 Beams..... | 38 |
| 6.1.1 Beams for buildings..... | 38 |
| 6.1.2 Effective width for verification of cross-sections..... | 40 |
| 6.2 Resistances of cross-sections of beams..... | 40 |
| 6.2.1 Bending resistance..... | 40 |
| 6.2.1.1 General..... | 40 |
| 6.2.1.2 Plastic resistance moment $M_{pl,Rd}$ of a composite cross-section..... | 40 |
| 6.2.1.3 Plastic resistance moment of sections with partial shear connection in buildings..... | 42 |
| 6.2.1.4 Non-linear resistance to bending..... | 43 |
| 6.2.1.5 Elastic resistance to bending..... | 44 |
| 6.2.2 Resistance to vertical shear..... | 45 |
| 6.2.2.1 Scope..... | 45 |
| 6.2.2.2 Plastic resistance to vertical shear..... | 45 |

| | |
|--|----|
| 6.2.2.3 Shear buckling resistance..... | 45 |
| 6.2.2.4 Bending and vertical shear..... | 45 |
| 6.3 Resistance of cross-sections of beams for buildings with partial encasement..... | 46 |
| 6.3.1 Scope..... | 46 |
| 6.3.2 Bending resistance..... | 46 |
| 6.3.3 Resistance to vertical shear..... | 47 |
| 6.3.4 Bending and vertical shear..... | 48 |
| 6.4 Lateral-torsional buckling of composite beams..... | 48 |
| 6.4.1 General..... | 48 |
| 6.4.2 Verification of lateral-torsional buckling of continuous composite beams with cross-sections in Class 1, 2 and 3 for buildings..... | 49 |
| 6.4.3 Simplified verification for buildings without direct calculation..... | 51 |
| 6.5 Transverse forces on webs..... | 52 |
| 6.5.1 General..... | 52 |
| 6.5.2 Flange-induced buckling of webs..... | 52 |
| 6.6 Shear connection..... | 52 |
| 6.6.1 General..... | 52 |
| 6.6.1.1 Basis of design..... | 52 |
| 6.6.1.2 Limitation on the use of partial shear connection in beams for buildings..... | 53 |
| 6.6.1.3 Spacing of shear connectors in beams for buildings..... | 54 |
| 6.6.2 Longitudinal shear force in beams for buildings..... | 55 |
| 6.6.2.1 Beams in which non-linear or elastic theory is used for resistances of one or more cross-sections..... | 55 |
| 6.6.2.2 Beams in which plastic theory is used for resistance of cross-sections..... | 55 |
| 6.6.3 Headed stud connectors in solid slabs and concrete encasement..... | 55 |
| 6.6.3.1 Design resistance..... | 55 |
| 6.6.3.2 Influence of tension on shear resistance..... | 56 |
| 6.6.4 Design resistance of headed studs used with profiled steel sheeting in buildings..... | 56 |
| 6.6.4.1 Sheeting with ribs parallel to the supporting beams..... | 56 |
| 6.6.4.2 Sheeting with ribs transverse to the supporting beams..... | 57 |
| 6.6.4.3 Biaxial loading of shear connectors..... | 58 |
| 6.6.5 Detailing of the shear connection and influence of execution..... | 58 |
| 6.6.5.1 Resistance to separation..... | 58 |
| 6.6.5.2 Cover and concreting for buildings..... | 58 |
| 6.6.5.3 Local reinforcement in the slab..... | 59 |
| 6.6.5.4 Haunches other than formed by profiled steel sheeting..... | 59 |
| 6.6.5.5 Spacing of connectors..... | 60 |
| 6.6.5.6 Dimensions of the steel flange..... | 60 |
| 6.6.5.7 Headed stud connectors..... | 60 |
| 6.6.5.8 Headed studs used with profiled steel sheeting in buildings..... | 61 |
| 6.6.6 Longitudinal shear in concrete slabs..... | 61 |
| 6.6.6.1 General..... | 61 |
| 6.6.6.2 Design resistance to longitudinal shear..... | 61 |
| 6.6.6.3 Minimum transverse reinforcement..... | 62 |
| 6.6.6.4 Longitudinal shear and transverse reinforcement in beams for buildings..... | 62 |

| | |
|---|-----------|
| 6.7 Composite columns and composite compression members..... | 63 |
| 6.7.1 General..... | 63 |
| 6.7.2 General method of design | 65 |
| 6.7.3 Simplified method of design..... | 66 |
| 6.7.3.1 General and scope..... | 66 |
| 6.7.3.2 Resistance of cross-sections..... | 67 |
| 6.7.3.3 Effective flexural stiffness, steel contribution ratio and relative slenderness..... | 69 |
| 6.7.3.4 Methods of analysis and member imperfections..... | 70 |
| 6.7.3.5 Resistance of members in axial compression..... | 70 |
| 6.7.3.6 Resistance of members in combined compression and uniaxial bending..... | 71 |
| 6.7.3.7 Combined compression and biaxial bending..... | 73 |
| 6.7.4 Shear connection and load introduction..... | 74 |
| 6.7.4.1 General..... | 74 |
| 6.7.4.2 Load introduction..... | 74 |
| 6.7.4.3 Longitudinal shear outside the areas of load introduction..... | 77 |
| 6.7.5 Detailing Provisions..... | 76 |
| 6.7.5.1 Concrete cover of steel profiles and reinforcement..... | 78 |
| 6.7.5.2 Longitudinal and transverse reinforcement..... | 78 |
| 6.8 Fatigue..... | 78 |
| 6.8.1 General..... | 78 |
| 6.8.2 Partial factors for fatigue assessment for buildings..... | 79 |
| 6.8.3 Fatigue strength..... | 79 |
| 6.8.4 Internal forces and fatigue loadings..... | 80 |
| 6.8.5 Stresses | 80 |
| 6.8.5.1 General..... | 80 |
| 6.8.5.2 Concrete..... | 80 |
| 6.8.5.3 Structural steel..... | 80 |
| 6.8.5.4 Reinforcement..... | 81 |
| 6.8.5.5 Shear connection..... | 81 |
| 6.8.6 Stress ranges..... | 82 |
| 6.8.6.1 Structural steel and reinforcement..... | 82 |
| 6.8.6.2 Shear connection..... | 82 |
| 6.8.7 Fatigue assessment based on nominal stress ranges..... | 83 |
| 6.8.7.1 Structural steel, reinforcement, and concrete..... | 83 |
| 6.8.7.2 Shear connection..... | 83 |
| Section 7 Serviceability limit states..... | 84 |
| 7.1 General..... | 84 |
| 7.2 Stresses..... | 84 |
| 7.2.1 General..... | 84 |
| 7.2.2 Stress limitation for buildings..... | 85 |
| 7.3 Deformations in buildings..... | 85 |
| 7.3.1 Deflections..... | 85 |
| 7.3.2 Vibration..... | 86 |
| 7.4 Cracking of concrete..... | 86 |
| 7.4.1 General..... | 86 |
| 7.4.2 Minimum reinforcement..... | 87 |
| 7.4.3 Control of cracking due to direct loading..... | 88 |

| | |
|---|-----------|
| Section 8 Composite joints in frames for buildings..... | 89 |
| 8.1 Scope..... | 89 |
| 8.2 Analysis, modelling and classification..... | 90 |
| 8.2.1 General..... | 90 |
| 8.2.2 Elastic global analysis..... | 90 |
| 8.2.3 Classification of joints..... | 90 |
| 8.3 Design methods..... | 91 |
| 8.3.1 Basis and scope..... | 91 |
| 8.3.2 Resistance..... | 91 |
| 8.3.3 Rotational stiffness..... | 91 |
| 8.3.4 Rotation capacity..... | 91 |
| 8.4 Resistance of components..... | 92 |
| 8.4.1 Scope..... | 92 |
| 8.4.2 Basic joint components..... | 92 |
| 8.4.2.1 Longitudinal steel reinforcement in tension..... | 92 |
| 8.4.2.2 Steel contact plate in compression..... | 92 |
| 8.4.3 Column web in transverse compression..... | 93 |
| 8.4.4 Reinforced components..... | 93 |
| 8.4.4.1 Column web panel in shear..... | 93 |
| 8.4.4.2 Column web in compression | 93 |
| Section 9 Composite slabs with profiled steel sheeting for buildings..... | 94 |
| 9.1 General..... | 94 |
| 9.1.1 Scope..... | 94 |
| 9.1.2 Definitions..... | 95 |
| 9.1.2.1 Types of shear connection..... | 95 |
| 9.1.2.2 Full shear connection am partial shear connection..... | 95 |
| 9.2 Detailing provisions..... | 96 |
| 9.2.1 Slab thickness and reinforcement..... | 96 |
| 9.2.2 Aggregate..... | 97 |
| 9.2.3 Bearing requirements..... | 97 |
| 9.3 Actions and action effects..... | 97 |
| 9.3.1 Design situations..... | 97 |
| 9.3.2 Actions for profiled steel sheeting as shuttering..... | 98 |
| 9.3.3 Actions for composite slab..... | 98 |
| 9.4 Analysis for internal forces and moments..... | 98 |
| 9.4.1 Profiled steel sheeting as shuttering..... | 98 |
| 9.4.2 Analysis of composite slab..... | 98 |
| 9.4.3 Effective width of composite slab for concentrated point and line loads..... | 99 |
| 9.5 Verification of profiled steel sheeting as shuttering for ultimate limit states..... | 100 |
| 9.6 Verification of profiled steel sheeting as shuttering for serviceability limit states..... | 100 |
| 9.7 Verification of composite slabs for ultimate limit states..... | 100 |
| 9.7.1 Design criterion..... | 100 |
| 9.7.2 Flexure..... | 101 |
| 9.7.3 Longitudinal shear for slabs without end anchorage..... | 102 |
| 9.7.4 Longitudinal shear for slabs with end anchorage..... | 104 |

| | |
|--|------------|
| 9.7.5 Vertical shear..... | 104 |
| 9.7.6 Punching shear..... | 104 |
| 9.8 Verification of composite slabs for serviceability limit states..... | 104 |
| 9.8.1 Control of cracking of concrete..... | 104 |
| 9.8.2 Deflection..... | 105 |
| Annex A (Informative) Stiffness of joint components in buildings..... | 106 |
| A.1 Scope..... | 106 |
| A.2 Stiffness coefficients..... | 106 |
| A.2.1 Basic joint components..... | 106 |
| A.2.1.1 Longitudinal steel reinforcement in tension..... | 106 |
| A.2.1.2 Steel contact plate in compression..... | 106 |
| A.2.2 Other components in composite joints..... | 108 |
| A.2.2.1 Column web panel in shear..... | 108 |
| A.2.2.2 Column web in transverse compression..... | 108 |
| A.2.3 Reinforced components..... | 108 |
| A.2.3.1 Column web panel in shear..... | 108 |
| A.2.3.2 Column web in transverse compression..... | 108 |
| A.3 Deformation of the shear connection..... | 109 |
| Annex B (Informative) Standard tests..... | 110 |
| B.1 General..... | 110 |
| B.2 Tests on shear connectors..... | 110 |
| B.2.1 General..... | 110 |
| B.2.2 Testing arrangements..... | 110 |
| B.2.3 Preparation of specimens..... | 111 |
| B.2.4 Testing procedure..... | 112 |
| B.2.5 Test evaluation..... | 112 |
| B.3 Testing of composite floor slabs..... | 113 |
| B.3.1 General..... | 113 |
| B.3.2 Testing arrangement..... | 114 |
| B.3.3 Preparation of specimens..... | 115 |
| B.3.4 Test loading procedure..... | 115 |
| B.3.5 Determination of design values for m and k | 116 |
| B.3.6 Determination of the design values for $\tau_{u,Rd}$ | 117 |
| Annex C (Informative) Shrinkage of concrete for composite structures for buildings..... | 118 |
| Bibliography..... | 118 |

Foreword

This document (EN 1994-1-1:2004), Eurocode 4: Design of composite steel and concrete structures: Part 1-1 General rules and rules for buildings, has been prepared on behalf of Technical Committee CEN/TC 250 "Structural Eurocodes", the Secretariat of which is held by BSI.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by June 2005, and conflicting national standards shall be withdrawn at the latest by March 2010.

This document supersedes ENV 1994-1-1:1992.

CEN/TC 250 is responsible for all Structural Eurocodes.

According to the CEN/CENELEC Internal Regulations, the national standards organizations of the following countries are bound to implement this European Standard: Austria, Belgium, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, the Netherlands, Norway, Poland, Portugal, Slovakia, Slovenia, Spain, Sweden, Switzerland and the 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 agreement¹ between the Commission and CEN, to transfer the preparation and the publication of the Eurocodes to CEN through a series of Mandates, in order to provide them with a future status of European Standard (EN). This links *de facto* the Eurocodes with the provisions of all the Council's Directives and/or Commission's Decisions dealing with European standards (*e.g.* the Council Directive 89/106/EEC on construction products - CPD - and 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).

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

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).

| | | |
|---------|-------------|---|
| 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 Documents² referred to in Article 12 of the CPD, although they are of a different nature from harmonised product standards³. Therefore, technical aspects arising from the Eurocodes work need to be adequately considered by CEN Technical Committees and/or EOTA Working Groups working on product standards 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.

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

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

- 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.

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 works⁴. 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 1994-1-1

EN 1994-1-1 describes the Principles and requirements for safety, serviceability and durability of composite steel and concrete structures, together with specific provisions for buildings. It is based on the limit state concept used in conjunction with a partial factor method.

For the design of new structures, EN 1994-1-1 is intended to be used, for direct application, together with other Parts of EN 1994, Eurocodes EN 1990 to 1993 and Eurocodes EN 1997 and 1998.

EN 1994-1-1 also serves as a reference document for other CEN TCs concerning structural matters.

EN 1994-1-1 is intended for use by:

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

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.

Numerical values for partial factors and other reliability parameters are recommended as basic values that provide an acceptable level of reliability. They have been selected assuming that an appropriate level of workmanship and of quality management applies. When EN 1994-1-1 is used as a base document by other CEN/TCs the same values need to be taken.

National annex for EN 1994-1-1

This standard gives values with notes indicating where national choices may have to be made. Therefore the National Standard implementing EN 1994-1-1 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 1994-1-1 through the following clauses:

- 2.4.1.1(1)
- 2.4.1.2(5)
- 2.4.1.2(6)
- 2.4.1.2(7)
- 3.1(4)
- 3.5(2)
- 6.4.3(1)(h)
- 6.6.3.1(1)
- 6.6.3.1(3)
- 6.6.4.1(3)
- 6.8.2(1)
- 6.8.2(2)
- 9.1.1(2)
- 9.6(2)
- 9.7.3(4)
- 9.7.3(8)
- 9.7.3(9)
- B.2.5(1)
- B.3.6(5)

Section 1 General

1.1 Scope

1.1.1 Scope of Eurocode 4

(1) Eurocode 4 applies to the design of composite structures and members for buildings and civil engineering works. It complies with the principles and requirements for the safety and serviceability of structures, the basis of their design and verification that are given in EN 1990 – Basis of structural design.

(2) Eurocode 4 is concerned only with requirements for resistance, serviceability, durability and fire resistance of composite structures. Other requirements, e.g. concerning thermal or sound insulation, are not considered.

(3) Eurocode 4 is intended to be used in conjunction with:

EN 1990 Eurocode: Basis of structural design

EN 1991 Eurocode 1: Actions on structures

ENs, hENs, ETAGs and ETAs for construction products relevant for composite structures

EN 1090 Execution of steel structures and aluminium structures

EN 13670 Execution of concrete structures

EN 1992 Eurocode 2: Design of concrete structures

EN 1993 Eurocode 3: Design of steel structures

EN 1997 Eurocode 7: Geotechnical design

EN 1998 Eurocode 8: Design of structures for earthquake resistance, when composite structures are built in seismic regions.

(4) Eurocode 4 is subdivided in various parts:

Part 1-1: General rules and rules for buildings

Part 1-2: Structural fire design

Part 2: Bridges.

1.1.2 Scope of Part 1-1 of Eurocode 4

(1) Part 1-1 of Eurocode 4 gives a general basis for the design of composite structures together with specific rules for buildings.

(2) The following subjects are dealt with in Part 1-1:

Section 1: General

Section 2: Basis of design

Section 3: Materials

Section 4: Durability

Section 5: Structural analysis

Section 6: Ultimate limit states

Section 7: Serviceability limit states

Section 8: Composite joints in frames for buildings

Section 9: Composite slabs with profiled steel sheeting for buildings

1.2 Normative references

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.

¹ To be published