

SINGAPORE STANDARD

Eurocode 4 : Design of composite steel and concrete structures

– Part 1-2 : General rules - Structural fire design

(This national standard is the identical implementation of EN 1994-1-2 : 2005 and is adopted with permission of CEN, Avenue Marnix 17, 1000 Brussels)

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concrete structures**

– Part 1-2 : General rules - Structural fire design

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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 1994-1-2 : 2005 'Eurocode 4: Design of composite steel and concrete structures – Part 1-2: General rules – Structural fire design' including its Corrigendum EN 1994-1-2:2005/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 1994-1-2 : 2009 are to be read in conjunction with the Singapore National Annex (NA) to SS EN 1994-1-2 : 2009 which contains information on the Singapore Nationally Determined Parameters and is published separately.

National choice is allowed in EN 1994-1-2 through the following clauses:

- 1.1(16)
- 2.1.3(2)
- 2.3(1)P
- 2.3(2)P
- 2.4.2(3)
- 3.3.2(9)
- 4.1(1)P
- 4.3.5.1(10)

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.

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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.*
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English Version

**Eurocode 4 - Design of composite steel and concrete structures
- Part 1-2: General rules - Structural fire design**

Eurocode 4 - Calcul des structures mixtes acier-béton -
Partie 1-2: Règles générales - Calcul du comportement au
feu

Eurocode 4 - Bemessung und Konstruktion von
Verbundtragwerken aus Stahl und Beton - Teil 1-2:
Allgemeine Regeln Tragwerksbemessung im Brandfall

This European Standard was approved by CEN on 4 November 2004.

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

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

CEN members are the national standards bodies of Austria, Belgium, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Slovakia, Slovenia, Spain, Sweden, Switzerland and United Kingdom.



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Contents	Page
Foreword	5
Background of the Eurocode programme.....	5
Status and field of application of Eurocodes	6
National Standards implementing Eurocodes	6
Links between Eurocodes and harmonised technical specifications (ENs and ETAs) for products	7
Additional information specific for EN 1994-1-2	7
National annex for EN 1994-1-2	10
Section 1 General	11
1.1 Scope	11
1.2 Normative references.....	13
1.3 Assumptions.....	15
1.4 Distinction between Principles and Application Rules	15
1.5 Definitions	15
1.5.1 Special terms relating to design in general.....	15
1.5.2 Terms relating to material and products properties.....	16
1.5.3 Terms relating to heat transfer analysis	16
1.5.4 Terms relating to mechanical behaviour analysis	16
1.6 Symbols	16
Section 2 Basis of design	26
2.1 Requirements.....	26
2.1.1 Basic requirements	26
2.1.2 Nominal fire exposure	26
2.1.3 Parametric fire exposure.....	27
2.2 Actions	27
2.3 Design values of material properties	27
2.4 Verification methods	28
2.4.1 General	28
2.4.2 Member analysis.....	29
2.4.3 Analysis of part of the structure	30
2.4.4 Global structural analysis.....	31
Section 3 Material properties	31
3.1 General	31
3.2 Mechanical properties.....	31
3.2.1 Strength and deformation properties of structural steel	31
3.2.2 Strength and deformation properties of concrete	33
3.2.3 Reinforcing steels	35
3.3 Thermal properties.....	36
3.3.1 Structural and reinforcing steels	36
3.3.2 Normal weight concrete	39
3.3.3 Light weight concrete	41
3.3.4 Fire protection materials	42
3.4 Density	42

Section 4	Design procedures	43
4.1	Introduction	43
4.2	Tabulated data	44
4.2.1	Scope of application	44
4.2.2	Composite beam comprising steel beam with partial concrete encasement	45
4.2.3	Composite columns	47
4.3	Simple Calculation Models	51
4.3.1	General rules for composite slabs and composite beams	51
4.3.2	Unprotected composite slabs	51
4.3.3	Protected composite slabs	52
4.3.4	Composite beams	53
4.3.5	Composite columns	61
4.4	Advanced calculation models	64
4.4.1	Basis of analysis	64
4.4.2	Thermal response	65
4.4.3	Mechanical response	65
4.4.4	Validation of advanced calculation models	65
Section 5	Constructional details	66
5.1	Introduction	66
5.2	Composite beams	66
5.3	Composite columns	67
5.3.1	Composite columns with partially encased steel sections	67
5.3.2	Composite columns with concrete filled hollow sections	67
5.4	Connections between composite beams and columns	68
5.4.1	General	68
5.4.2	Connections between composite beams and composite columns with steel sections encased in concrete	69
5.4.3	Connections between composite beams and composite columns with partially encased steel sections	70
5.4.4	Connections between composite beams and composite columns with concrete filled hollow sections	70
Annex A (INFORMATIVE)	Stress-strain relationships at elevated temperatures for structural steels	72
Annex B (INFORMATIVE)	Stress-strain relationships at elevated temperatures for concrete with siliceous aggregate	75
Annex C (INFORMATIVE)	Concrete stress-strain relationships adapted to natural fires with a decreasing heating branch for use in advanced calculation models	77
Annex D (INFORMATIVE)	Model for the calculation of the fire resistance of unprotected composite slabs exposed to fire beneath the slab according to the standard temperature-time curve	79
D.1	Fire resistance according to thermal insulation	79
D.2	Calculation of the sagging moment resistance $M_{fi,Rd}^+$	80
D.3	Calculation of the hogging moment resistance $M_{fi,Rd}^-$	82
D.4	Effective thickness of a composite slab	84
D.5	Field of application	85

Annex E (INFORMATIVE)	Model for the calculation of the sagging and hogging moment resistances of a steel beam connected to a concrete slab and exposed to fire beneath the concrete slab.	86
E.1	Calculation of the sagging moment resistance $M_{fi,Rd}^+$	86
E.2	Calculation of the hogging moment resistance $M_{fi,Rd}^-$ at an intermediate support (or at a restraining support)	87
E.3	Local resistance at supports	88
E.4	Vertical shear resistance	89
Annex F (INFORMATIVE)	Model for the calculation of the sagging and hogging moment resistances of a partially encased steel beam connected to a concrete slab and exposed to fire beneath the concrete slab according to the standard temperature-time curve.	90
F.1	Reduced cross-section for sagging moment resistance $M_{fi,Rd}^+$	90
F.2	Reduced cross-section for hogging moment resistance $M_{fi,Rd}^-$	94
F.3	Field of application	95
Annex G (INFORMATIVE)	Balanced summation model for the calculation of the fire resistance of composite columns with partially encased steel sections, for bending around the weak axis, exposed to fire all around the column according to the standard temperature-time curve.	96
G.1	Introduction	96
G.2	Flanges of the steel profile	97
G.3	Web of the steel profile	97
G.4	Concrete	98
G.5	Reinforcing bars	99
G.6	Calculation of the axial buckling load at elevated temperatures	100
G.7	Eccentricity of loading	101
G.8	Field of application	101
Annex H (INFORMATIVE)	Simple calculation model for concrete filled hollow sections exposed to fire all around the column according to the standard temperature-time curve.	104
H.1	Introduction	104
H.2	Temperature distribution	104
H.3	Design axial buckling load at elevated temperature	104
H.4	Eccentricity of loading	105
H.5	Field of application	105
Annex I (INFORMATIVE)	Planning and evaluation of experimental models	109
I.1	Introduction	109
I.2	Test for global assessment	109
I.3	Test for partial information	109

Foreword

This European Standard EN 1994-1-2: 2005, Eurocode 4: Design of composite steel and concrete structures: Part 1-2 : General rules – Structural fire design, has been prepared by Technical Committee CEN/TC250 « Structural Eurocodes », the Secretariat of which is held by BSI.

CEN/TC250 is responsible for all Structural Eurocodes.

This European Standard shall be given the status of a National Standard, either by publication of an identical text or by endorsement, at the latest by February 2006, and conflicting National Standards shall be withdrawn at latest by March 2010.

This Eurocode supersedes ENV 1994-1-2: 1994.

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

Background of the Eurocode programme

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

Within this action programme, the Commission took the initiative to establish a set of harmonised technical rules for the design of construction works which, in a first stage, would serve as an alternative to the 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 agreement¹ between the Commission and CEN, to transfer the preparation and the publication of the Eurocodes to the 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:

EN1990, Eurocode : Basis of structural design

EN1991, Eurocode 1: Actions on structures

EN1992, Eurocode 2: Design of concrete structures

EN1993, Eurocode 3: Design of steel structures

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 1994-1-2:2005 (E)

EN1994, Eurocode 4: Design of composite steel and concrete structures

EN1995, Eurocode 5: Design of timber structures

EN1996, Eurocode 6: Design of masonry structures

EN1997, Eurocode 7: Geotechnical design

EN1998, Eurocode 8: Design of structures for earthquake resistance

EN1999, 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.

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.

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

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

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

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

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, 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 for EN 1994-1-2

EN 1994-1-2 describes the Principles, requirements and rules for the structural design of buildings exposed to fire, including the following aspects:

Safety requirements

EN 1994-1-2 is intended for clients (e.g. for the formulation of their specific requirements), designers, contractors and public authorities.

The general objectives of fire protection are to limit risks with respect to the individual and society, neighbouring property, and where required, environment or directly exposed property, in the case of fire.

Construction Products Directive 89/106/EEC gives the following essential requirement for the limitation of fire risks:

"The construction works must be designed and built in such a way, that in the event of an outbreak of fire

- the load bearing resistance of the construction can be assumed for a specified period of time;
- the generation and spread of fire and smoke within the works are limited;
- the spread of fire to neighbouring construction works is limited;
- the occupants can leave the works or can be rescued by other means;
- the safety of rescue teams is taken into consideration".

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 N°1.

⁵ see clauses 2.2, 3.2(4) and 4.2.3.3 of ID N°2

EN 1994-1-2:2005 (E)

According to the Interpretative Document N°2 "Safety in Case of Fire⁵" the essential requirement may be observed by following various possibilities for fire safety strategies prevailing in the Member States like conventional fire scenarios (nominal fires) or "natural" (parametric) fire scenarios, including passive and/or active fire protection measures.

The fire parts of Structural Eurocodes deal with specific aspects of passive fire protection in terms of designing structures and parts thereof for adequate load bearing resistance and for limiting fire spread as relevant.

Required functions and levels of performance can be specified either in terms of nominal (standard) fire resistance rating, generally given in national regulations or, where allowed by national fire regulations, by referring to fire safety engineering for assessing passive and active measures.

Supplementary requirements concerning, for example

- the possible installation and maintenance of sprinkler systems;
- conditions on occupancy of building or fire compartment;
- the use of approved insulation and coating materials, including their maintenance.

are not given in this document, because they are subject to specification by the competent authority.

Numerical values for partial factors and other reliability elements are given as recommended values that provide an acceptable level of reliability. They have been selected assuming that an appropriate level of workmanship and of quality management applies.

Design procedures

A full analytical procedure for structural fire design would take into account the behaviour of the structural system at elevated temperatures, the potential heat exposure and the beneficial effects of active fire protection systems, together with the uncertainties associated with these three features and the importance of the structure (consequences of failure).

At the present time it is possible to undertake a procedure for determining adequate performance which incorporates some, if not all, of these parameters and to demonstrate that the structure, or its components, will give adequate performance in a real building fire. However where the procedure is based on a nominal (standard) fire, the classification system, which calls for specific periods of fire resistance, takes into account (though not explicitly), the features and uncertainties described above.

Application of this Part 1-2 is illustrated below. The prescriptive approach and the performance-based approach are identified. The prescriptive approach uses nominal fires to generate thermal actions. The performance-based approach, using fire safety engineering, refers to thermal actions based on physical and chemical parameters.

For design according to this part, EN 1991-1-2 is required for the determination of thermal and mechanical actions to the structure.

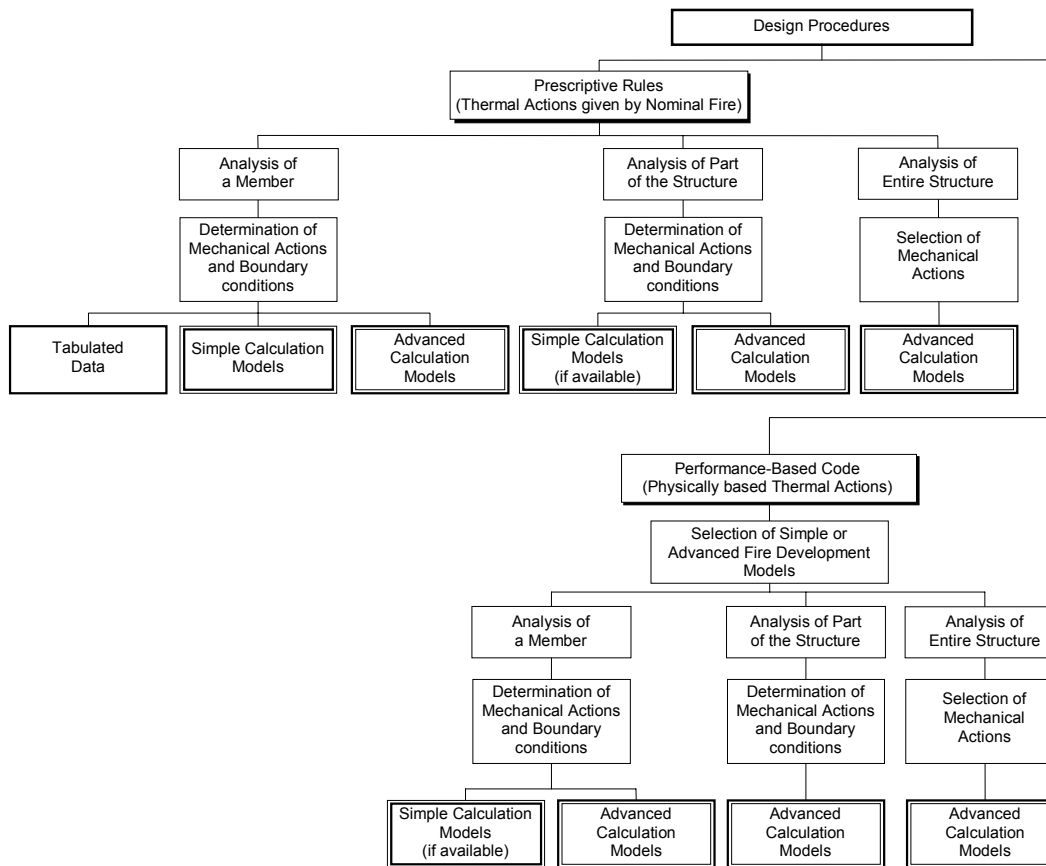


Figure 0.1: Alternative design procedures

Design aids

Apart from simple calculation models, EN 1994-1-2 gives design solutions in terms of tabulated data (based on tests or advanced calculation models) which may be used within the specified limits of validity.

It is expected, that design aids based on the calculation models given in EN 1994-1-2, will be prepared by interested external organizations.

The main text of EN 1994-1-2 together with informative Annexes A to I includes most of the principal concepts and rules necessary for structural fire design of composite steel and concrete structures.

National annex for EN 1994-1-2

This standard gives alternative procedures, values and recommendations for classes with notes indicating where national choices may have to be made. Therefore the National Standard implementing EN 1994-1-2 should have a National annex containing all Nationally Determined Parameters to be used for the design of buildings to be constructed in the relevant country.

National choice is allowed in EN 1994-1-2 through clauses:

- 1.1(16)
- 2.1.3(2)
- 2.3(1)P
- 2.3(2)P
- 2.4.2(3)
- 3.3.2(9)
- 4.1(1)P
- 4.3.5.1(10)

Section 1 General

1.1 Scope

(1) This Part 1-2 of EN 1994 deals with the design of composite steel and concrete structures for the accidental situation of fire exposure and is intended to be used in conjunction with EN 1994-1-1 and EN 1991-1-2. This Part 1-2 only identifies differences from, or supplements to, normal temperature design.

(2) This Part 1-2 of EN 1994 deals only with passive methods of fire protection. Active methods are not covered.

(3) This Part 1-2 of EN 1994 applies to composite steel and concrete structures that are required to fulfil certain functions when exposed to fire, in terms of:

- avoiding premature collapse of the structure (load bearing function);
- limiting fire spread (flame, hot gases, excessive heat) beyond designated areas (separating function).

(4) This Part 1-2 of EN 1994 gives principles and application rules (see EN 1991-1-2) for designing structures for specified requirements in respect of the aforementioned functions and the levels of performance.

(5) This Part 1-2 of EN 1994 applies to structures, or parts of structures, that are within the scope of EN 1994-1-1 and are designed accordingly. However, no rules are given for composite elements which include prestressed concrete parts.

(6) For all composite cross-sections longitudinal shear connection between steel and concrete should be in accordance with EN 1994-1-1 or be verified by tests (see also 4.3.4.1.5 and Annex I).

(7) Typical examples of concrete slabs with profiled steel sheets with or without reinforcing bars are given in Figure 1.1.

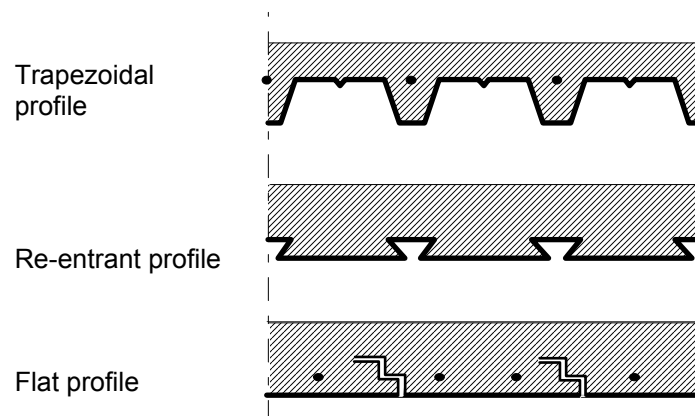
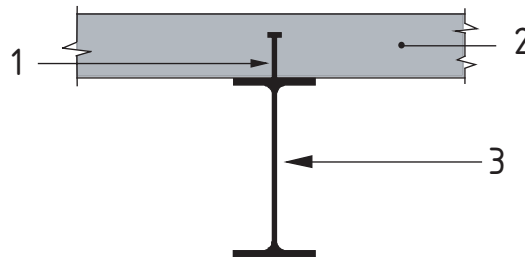


Figure 1.1 Typical examples of concrete slabs with profiled steel sheets with or without reinforcing bars

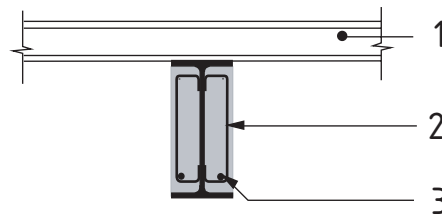
(8) Typical examples of composite beams are given in Figures 1.2 to 1.5. The corresponding constructional detailing is covered in section 5.



Key

- 1 – Shear connectors
- 2 – Flat concrete slab or composite slab with profiled steel sheeting
- 3 – Profiles with or without protection

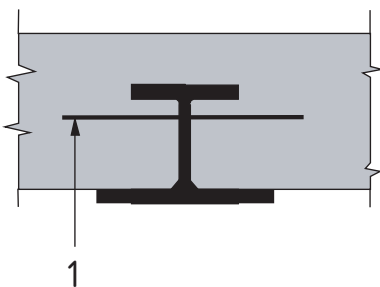
Figure 1.2: Composite beam comprising steel beam with no concrete encasement



Key

- 1 – Optional
- 2 – Stirrups welded to web of profile
- 3 – Reinforcing bar

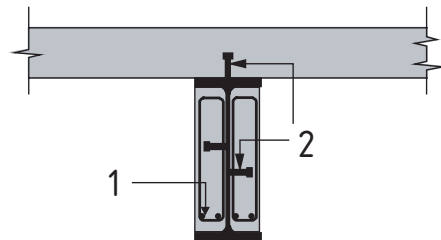
Figure 1.3: Steel beam with partial concrete encasement



Key

- 1 – Reinforcing bar

Figure 1.4: Steel beam partially encased in slab



Key

- 1 – Reinforcing bar
- 2 – Shear connectors

Figure 1.5: Composite beam comprising steel beam with partial concrete encasement

(9) Typical examples of composite columns are given in Figures 1.6 to 1.8. The corresponding constructional detailing is covered in section 5.

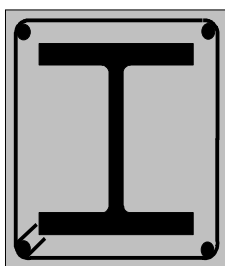
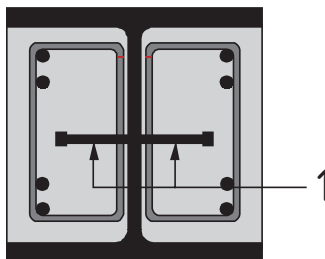


Figure 1.6:
Concrete encased profiles



Key
1 – Shear connectors welded to web of profile

Figure 1.7:
Partially encased profiles

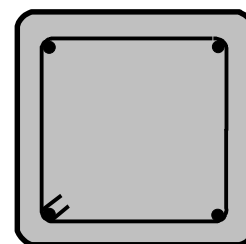


Figure 1.8:
Concrete filled profiles

(10) Different shapes, like circular or octagonal cross-sections may also be used for columns. Where appropriate, reinforcing bars may be replaced by steel sections.

(11) The fire resistance of these types of constructions may be increased by applying fire protection materials.

NOTE: The design principles and rules given in 4.2, 4.3 and 5 refer to steel surfaces directly exposed to the fire, which are free of any fire protection material, unless explicitly specified otherwise.

(12)P The methods given in this Part 1-2 of EN 1994 are applicable to structural steel grades S235, S275, S355, S420 and S460 of EN 10025, EN 10210-1 and EN 10219-1.

(13) For profiled steel sheeting, reference is made to section 3.5 of EN 1994-1-1.

(14) Reinforcing bars should be in accordance with EN 10080.

(15) Normal weight concrete, as defined in EN 1994-1-1, is applicable to the fire design of composite structures. The use of lightweight concrete is permitted for composite slabs.

(16) This part of EN 1994 does not cover the design of composite structures with concrete strength classes lower than C20/25 and LC20/22 and higher than C50/60 and LC50/55.

NOTE : Information on Concrete Strength Classes higher than C50/60 is given in section 6 of EN 1992-1-2. The use of these concrete strength classes may be specified in the National Annex.

(17) For materials not included herein, reference should be made to relevant CEN product standards or European Technical Approval (ETA).

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).

EN 1365 -1	Fire resistance tests for loadbearing elements – Part 1: Walls
EN 1365 -2	Fire resistance tests for loadbearing elements – Part 2: Floors and roofs
EN 1365 -3	Fire resistance tests for loadbearing elements – Part 3: Beams

EN 1994-1-2:2005 (E)

EN 1365 -4	Fire resistance tests for loadbearing elements – Part 4: Columns
EN 10025-1	Hot-rolled products of structural steels - Part 1: General technical delivery conditions
EN 10025-2	Hot-rolled products of structural steels - Part 2: Technical delivery conditions for non-alloy structural steels
EN 10025-3	Hot-rolled products of structural steels - Part 3: Technical delivery conditions for normalized/normalized rolled weldable fine grain structural steels
EN 10025-4	Hot-rolled products of structural steels - Part 4: Technical delivery conditions for thermomechanical rolled weldable fine grain structural steels
EN 10025-5	Hot-rolled products of structural steels - Part 5: Technical delivery conditions for structural steels with improved atmospheric corrosion resistance
EN 10025-6	Hot-rolled products of structural steels - Part 6: Technical delivery conditions for flat products of high yield strength structural steels in the quenched and tempered condition
EN 10080	Steel for the reinforcement of concrete - Weldable reinforcing steel General
EN 10210-1	Hot finished structural hollow sections of non-alloy and fine grain structural steels – Part 1 : Technical delivery conditions
EN 10219-1	Cold formed welded structural hollow sections of non-alloy and fine grain structural steels – Part 1: Technical delivery conditions
ENV 13381-1	Test methods for determining the contribution to the fire resistance of structural members – Part 1: Horizontal protective membranes
ENV 13381-2	Test methods for determining the contribution to the fire resistance of structural members – Part 2: Vertical protective membranes
ENV 13381-3	Test methods for determining the contribution to the fire resistance of structural members – Part 3: Applied protection to concrete members
ENV 13381-4	Test methods for determining the contribution to the fire resistance of structural members – Part 4: Applied protection to steel members
ENV 13381-5	Test methods for determining the contribution to the fire resistance of structural members – Part 5: Applied protection to concrete/profiled sheet composite members
ENV 13381-6	Test methods for determining the contribution to the fire resistance of structural members – Part 6: Applied protection to concrete filled hollow sheet columns
EN 1990	Eurocode: Basis of structural design
EN 1991 -1-1	Eurocode 1 : Actions on Structures – Part 1.1: General Actions - Densities, self-weight and imposed loads
EN 1991 -1-2	Eurocode 1 : Actions on Structures – Part 1.2: General Actions - Actions on structures exposed to fire

EN 1991 -1-3	Eurocode 1 : Actions on Structures – Part 1.3: General Actions - Actions on structures - Snow loads
EN 1991 -1-4	Eurocode 1 : Actions on Structures – Part 1.4: General Actions - Actions on structures - Wind loads
EN 1992-1-1	Eurocode 2: Design of concrete structures - Part 1.1: General rules and rules for buildings
EN 1992-1-2	Eurocode 2: Design of concrete structures - Part 1.2: Structural fire design
EN 1993-1-1	Eurocode 3: Design of steel structures - Part 1.1: General rules and rules for buildings
EN 1993-1-2	Eurocode 3: Design of steel structures - Part 1.2: Structural fire design
EN 1993-1-5	Eurocode 3: Design of steel structures - Part 1.5: Plated structural elements
EN 1994-1-1	Eurocode 4: Design of composite steel and concrete structures - Part 1.1: General rules and rules for buildings"