

Eurocode 4: Design of composite steel and concrete structures —

**Part 1.1: General rules and rules for
buildings —**

**(together with United Kingdom
National Application Document)**

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This Draft for Development, having been prepared under the direction of the Technical Sector Board for Building and Civil Engineering (B/-), was published under the authority of the Standards Board and comes into effect on 15 May 1994

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National foreword

This publication comprises the English language version of ENV 1994-1-1:1992 *Eurocode 4: Design of composite steel and concrete structures — Part 1.1: General rules and rules for buildings*, as published by the European Committee for Standardization (CEN), plus the National Application Document to be used with the ENV in the design of buildings to be constructed in the United Kingdom.

ENV 1994-1-1:1992 results from a programme of work sponsored by the European Commission to make available a common set of rules for the design of building and civil engineering works.

An ENV is made available for provisional application, but does not have the status of a European Standard. The aim is to use the experience gained to modify the ENV so that it can be adopted as a European Standard.

The values for certain parameters in the ENV Eurocodes may be set by CEN members so as to meet the requirements of national regulations. These parameters are designated by $\square$ in the ENV.

During the ENV period of validity, reference should be made to the supporting documents listed in the National Application Document (NAD).

The purpose of the NAD is to provide essential information, particularly in relation to safety, to enable the ENV to be used for buildings constructed in the UK. The NAD takes precedence over corresponding provisions in the ENV.

The Building Regulations 1991, Approved Document A 1992, (published December 1991) draws designers' attention to the potential use of ENV Eurocodes as an alternative approach to Building Regulation compliance.

ENV 1994-1-1:1992 has been thoroughly examined over a period of several years and is considered to offer such an alternative approach, when used in conjunction with the NAD.

Compliance with ENV 1994-1-1:1992 and the NAD does not in itself confer immunity from legal obligations.

Users of this document are invited to comment on its technical content, ease of use and any ambiguities or anomalies. These comments will be taken into account when preparing the UK national response to CEN on the question of whether the ENV can be converted to an EN.

Comments should be sent in writing to BSI, 2 Park Street, London W1A 2BS, quoting the document reference, the relevant clause and, where possible, a proposed revision, within 2 years of the issue of this document.

Summary of pages

This document comprises a front cover, an inside front cover, pages i to xxii, the ENV title page, pages 2 to 134, an inside back cover and a back cover.

This standard has been updated (see copyright date) and may have had amendments incorporated. This will be indicated in the amendment table on the inside front cover.

National Application Document

**for use in the UK with
ENV 1994-1-1:1992**

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Introduction

This National Application Document (NAD) has been prepared under the direction of the Civil Engineering and Technical Sector Board for Buildings and Civil Engineering. It has been developed from:

- a) a textual examination of ENV 1994-1-1:1992;
- b) calibration against UK practice, supporting standards and test data;
- c) trial calculations.

1 Scope

This NAD provides information required to enable ENV 1994-1-1:1992 (EC4-1.1) to be used for the design of buildings to be constructed in the UK.

2 References

2.1 Normative references

This National Application Document incorporates, by reference, provisions from specific editions of other publications. These normative references are cited at the appropriate points in the text and the publications are listed on page xx. Subsequent amendments to, or revisions of, any of these publications apply to this National Application Document only when incorporated in it by updating or revision.

2.2 Informative references

This National Application Document refers to other publications that provide information or guidance. Editions of these publications current at the time of issue of this standard are listed on page xx, but reference should be made to the latest editions.

3 Partial safety factors, combination factors and other values

- a) The values for partial safety factors (γ) should be those given in Table 1 of this NAD.
- b) The values for combination factors (Ψ) should be those given in Table 2 and Table 3 of this NAD.
- c) The values for the boxed factors should be those given in Table 4 of this NAD.

Table 1 — Partial safety factors (γ factors)

Reference in EC4-1.1	Definition	Symbol	Condition	Value	
				Boxed EC4	UK
2.3.2.2 1)	Partial safety factor for accidental actions	γ_A	Accidental	1.00	1.05
2.3.2.2 3)	Partial safety factor for permanent actions in accidental design situations	γ_{GA}	Favourable	1.00	0.90
		γ_{GA}	Unfavourable	1.00	1.05
2.3.3.1 1)	Partial safety factors for permanent actions	$\gamma_{G.inf}$	Favourable	1.00	1.00
		$\gamma_{G.sup}$	Unfavourable	1.35	1.35
2.3.3.1 1)	Partial safety factors for variable actions	$\gamma_{Q.inf}$	Favourable	0.00	0.00
		$\gamma_{Q.sup}$	Unfavourable	1.50	1.50
		$\gamma_{Q.sup}$	2 or more combined	1.50	1.50
2.3.3.1 3)	Partial safety factors for permanent actions	$\gamma_{G.inf}$	Favourable part	1.10	1.10
		$\gamma_{G.sup}$	Unfavourable part	1.35	1.35
		$\gamma_{G.inf}$	Favourable and unfavourable parts	1.00	1.00

Table 1 — Partial safety factors (γ factors)

Reference in EC4-1.1	Definition	Symbol	Condition	Value	
				Boxed EC4	UK
2.3.3.2 1)	Partial safety factors for structural steel	γ_a	Fundamental	1.10	1.05
		γ_a	Accidental (except earthquakes)	1.00	1.05
2.3.3.2 1)	Partial safety factors for concrete	γ_c	Fundamental	1.50	1.50
		γ_c	Accidental (except earthquakes)	1.30	1.30
2.3.3.2 1)	Partial safety factors for steel reinforcement	γ_s	Fundamental	1.15	1.15
		γ_s	Accidental (except earthquakes)	1.00	1.00
2.3.3.2 1)	Partial safety factors for profiled steel sheeting	γ_{ap}	Fundamental	1.10	1.05
		γ_{ap}	Accidental (except earthquakes)	1.00	1.05
2.3.3.2 2)	Partial safety factors for elastic mechanical properties	γ_M	General	1.00	1.00
2.3.3.2 2)	Partial safety factors for non-mechanical coefficients	γ_M	General	1.00	1.00
4.1.1 5)	Partial safety factors for the buckling resistance of structural steel	γ_{Rd}	Accidental combinations	1.00	1.05
4.4.1.4 3)	Partial safety factors for steel	γ_{Rd}	Resistance of Class 4 cross sections	1.10	1.05
4.6.3 1)	Partial safety factors for steel	γ_{Rd}	Resistance of Class 1 or 2 cross sections	1.10	1.05
		γ_{Rd}	Resistance of Class 3 cross sections	1.10	1.05
4.8.3.2 1)	Partial safety factors for steel	γ_{Ma}	For a column length with	1.10	1.05
		γ_{Ma}	$\lambda \leq 0.2$ or $N_{sd}/N_{cr} \leq 0.1$ otherwise	1.10	1.05
4.8.3.5 1)	Partial safety factors for the elastic flexural stiffness of concrete	γ_c		1.35	1.35
6.3.2.1	Partial safety factors for shear studs	γ_v	Ultimate limit state	1.25	1.25
6.3.7	Partial safety factors for angle connectors in solid slabs	γ_v	Ultimate limit state	1.25	1.25
6.5.2.1 1)	Partial safety factors for friction grip bolts	γ_v		1.25	1.35
7.6.1.3 2)	Partial safety factors for slabs with mechanical or frictional interlock	γ_{vs}	For use in equation 7.6	1.25	1.25
10.2.5 1)	Partial safety factor for shear connectors	γ_v	Test evaluation	1.25	1.25

Table 1 — Partial safety factors (γ factors)

Reference in EC4-1.1	Definition	Symbol	Condition	Value	
				Boxed EC4	UK
E.2 5)	Partial safety factor for shear connection	γ_v	Shear strength	1.25	1.25
E.4 4)	Partial safety factor for shear connection	γ_v	End anchorage	1.25	1.25

Table 2 — Combination factors (Ψ factors) for persistent and transient design situations

Variable action ^a		Ψ_0	Ψ_1	Ψ_2
Imposed floor loads	Dwellings	0.5	0.4	0.2
	Office and stores	0.7	0.6	0.3
	Parking	0.7	0.7	0.6
Wind loads		0.7	0.2	0
Imposed roof loads ^b		0.7	0.2	0
Crane loads ^c	Vertical	0.7	0.6	0.3
	Horizontal			
	0.9 (Vertical and Horizontal)			

^a For the purposes of EC4-1.1 these four categories of variable action should be treated as separate and independent variable actions.

^b Local drifting of snow on roofs should be treated as an accidental action [see 6.1.1 c)].

^c The most onerous of the three specified alternatives should be treated as a single variable action.

Table 3 — Combination factors for accidental design situations

Variable action		Ψ_1 or Ψ_2 for use in A.3 and A.4
Imposed floor loads	Dwellings	0.35 ^a
	Offices	0.35 ^a
	Stores	1.0
	Parking	0.35 ^a
Wind loads ^b		0.35
Imposed roof loads		0.35
Crane loads ^c	Vertical	1.00
	Horizontal	0.00

^a Where the variable action is of a persistent or quasi-permanent nature, the Ψ factor should be taken as 1.0.

^b The full value obtained from CP 3 Chapter V-2 should be multiplied by 0.35

^c The values given in this table assume that the crane is stationary. The vertical load to which the combination factor is applied is the static load value.

Table 4 — Boxed values

Reference in EC4-1.1	Definition	Symbol	Condition	Value	
				Boxed EC4	UK
3.1.3 2)	Long-term free shrinkage strain from setting of the concrete: dry environments	ϵ_{cs}	Normal-weight concrete	325×10^{-6}	325×10^{-6}
		ϵ_{cs}	Light-weight concrete	500×10^{-6}	500×10^{-6}
3.1.3 2)	Long-term free shrinkage strain from setting of the concrete: other environments and in filled members	ϵ_{cs}	Normal-weight concrete	200×10^{-6}	200×10^{-6}
		ϵ_{cs}	Light-weight concrete	300×10^{-6}	300×10^{-6}
4.8.3.13 6)	% reduction in the partial safety factor for the favourable component N_{sd}			20 %	30 %
5.3.2 2)	Minimum tensile strength of concrete	f_{cte}		3 N/mm ²	3 N/mm ²
10.2.5 1)	Reduction for the characteristic resistance P_{Rk}			10 %	10 %
10.2.5 4)	Reduction for the characteristic slip capacity			10 %	10 %
10.3.1.5 5)	Reduction for the characteristic values m and k			10 %	10 %
10.3.2.5	Design resistance of composite slab		a)	0.75	0.75
			b)	0.5	0.5
			c)	0.75	0.75
E.2 4)	Reduction for the characteristic shear strength			10 %	10 %
E.4 3)	Reduction for the characteristic resistance of the end anchorage			10 %	10 %
E.5 4)	Lower limit on bending resistance			10 %	10 %

4 Loading codes

The loading codes to be used are:

BS 648:1964	<i>Schedule of weights of building materials</i>
BS 6399:	<i>Design loading for buildings</i>
BS 6399-1:1984	<i>Code of practice for dead and imposed loads</i>
BS 6399-3:1988	<i>Code of practice for imposed roof loads</i>
CP3:	<i>Code of basic data for the design of buildings</i>
CP3:Chapter V:	<i>Loading</i>
CP3:Chapter V-2:1972	<i>Wind loads</i>
BS 5950:	<i>Structural use of steelwork in building</i>
BS 5950-3:	<i>Design in composite construction</i>
BS 5950-3.1:1990	<i>Code of practice for design of simple and continuous composite beams</i>
	Clause 2.2 Loading

BS 5950-4:1993	<i>Code of practice for design of composite slabs with profiled steel sheeting</i> Clause 2.2 Loading
BS 5975:1982	<i>Code of practice for falsework</i> Section 4 Loads applied to falsework

In using the above documents with EC4-1.1 the following modifications should be noted:

- The imposed floor loads of a building should be treated as one variable action to which the reduction factors given in BS 6399-1:1984 are applicable.
- The characteristic wind loading should be taken as 90 % of the value obtained from CP3:Chapter V-2:1972.

5 Reference standards

The supporting standards to be used, including materials specifications and standards for construction are listed in Table 5.

Table 5 — References in EC4-1.1 to other codes and standards

Reference in EC4-1.1	Document referred to	Document title or subject area	Status	UK document
1.1.1 3)	Eurocode 2	<i>Design of concrete structures</i> Part 1. <i>General rules and rules for buildings</i>	ENV 1992-1-1	DD ENV 1992-1-1 (See note 1)
		Part 1A <i>Plain or lightly-reinforced concrete structures</i>	Draft	BS 8110-1, and section 8 of BS 8110-2:1985
		Part 1B <i>Precast concrete structures</i>	Draft	BS 8110-1
		Part 1C <i>The use of lightweight aggregate concrete</i>	Draft	Section 5 of BS 8110-2:1985
		Part 1D <i>The use of unbonded and external prestressing tendons</i>	No draft	Section 8 of BS 8110-1:1985
		Part 10. <i>Fire resistance of concrete structures</i>	Draft	BS 8110-1 and section 4 of BS 8110-2:1985
1.1.1 3)	Eurocode 3	<i>Design of steel structures</i> Part 1.1 <i>General rules and rules for buildings</i>	ENV 1993-1-1	DD ENV 1993-1-1 (See note 1)
		Part 1.2 <i>Fire resistance</i>	Draft	Section 7 of BS 5950-4:1993 BS 5950-8
		Part 1.3 <i>Cold formed thin gauge members and sheeting</i>	Draft	BS 5950-4, BS 5950-6 (See note 6) and BS 5950-7
1.1.1 4)	Eurocode 8	<i>Design of structures for earthquake resistance</i>	In preparation	—
1.1.1 5)	Eurocode 1	<i>Basis of design and actions on structures</i>	In preparation	BS 6399-1 and BS 6399-3 CP3: Chapter V-2 2.2 of BS 5950-3.1:1990 2.2 of BS 5950-4:1993 Section 4 of BS 5975:1982
1.1.2 5)	Eurocode 2	<i>Design of concrete structures</i> Part 1 <i>General rules and rules for buildings</i>	ENV 1992-1-1	DD ENV 1992-1-1
	Eurocode 3	<i>Design of steel structures</i> Part 1.1 <i>General rules and rules for buildings</i>	ENV 1993-1-1	DD ENV 1993-1-1
1.1.3 2)	Eurocode 4	<i>Design of composite steel and concrete structures</i> Part 1.2 <i>Fire resistance</i>	Draft	Section 7 of BS 5950-4:1993 BS 5950-8
				BS 8110-1 Section 4 of BS 8110-2:1985
1.4.1 1)	ISO 8930	<i>General principles on reliability of structures — List of equivalent terms</i>	Published 1987	—
1.4.1 2)	ISO 6707-1	<i>Building and civil engineering — Vocabulary — Part 1: General terms</i>	Published 1989	—
1.5 1)	ISO 1000	<i>SI units and recommendations for the use of their multiples and of certain other units</i>	Published 1981	—

Table 5 — References in EC4-1.1 to other codes and standards

Reference in EC4-1.1	Document referred to	Document title or subject area	Status	UK document
2.2.1.1 4)	Eurocode 2	<i>Design of concrete structures</i>		
		Part 1 <i>General rules and rules for buildings</i>	ENV 1992-1-1	DD ENV 1992-1-1 (See note 1)
		Part 1A <i>Plain or lightly-reinforced concrete structures</i>	Draft	3.8.1.4 and 3.9.4 of BS 8110-1:1985
		Part 1B <i>Precast concrete structures</i>	Draft	Section 5 of BS 8110-1:1985
		Part 1C <i>The use of lightweight aggregate concrete</i>	Draft	Section 5 of BS 8110-2:1985
		Part 1D <i>The use of unbonded and external prestressing tendons</i>	No draft	Section 4 of BS 8110-1:1985
		Part 10 <i>Fire resistance of concrete structures</i>	Draft	3.3.6 of BS 8110-1:1985 Section 4 of BS 8110-2:1985
2.2.1.1 4)	Eurocode 3	<i>Design of steel structures</i>		
		Part 1.1 <i>General rules and rules for buildings</i>	ENV 1993-1-1	DD ENV 1993-1-1 (See note 1)
		Part 1.2 <i>Fire resistance</i>	Draft	Section 7 of BS 5950-4:1993 BS 5950-8
		Part 1.3 <i>Cold formed thin gauge members and sheeting</i>	Draft	BS 5950-4, BS 5950-5 and BS 5950-6 (See note 6)
Chapter 2 [except 2.3.1 3)]	Eurocode 1	<i>Basis of design and actions on structures</i>	In preparation	BS 6399-1 and BS 6399-3 CP3:Chapter V-2 2.2 of BS 5950-3.1:1990 2.2 and 5.3 of BS 5950-4:1993 (See note 2) Section 4 of BS 5975:1982 DD ENV 1994-1-1
2.2.2.2 1)	“other relevant loading codes”			
2.3.1 3) ENV note	Eurocode 1	<i>Basis of design and actions on structures</i>	In preparation	DD ENV 1994-1-1
3.1.2 2) ENV note		Variation in time of f_c and f_{ct}	—	7.2 of BS 8110-2:1985 3.1.2.3 of DD ENV 1992-1-1:1992
3.2	EN 10080	<i>Steel for the reinforcement of concrete</i>	Draft	See below
3.2.3 2)	“national documents”	Reinforcing steel not covered by EN 10080	—	BS 4449 BS 4482 BS 4483
3.3 3.4	EN 10025	<i>Hot rolled products of non-alloy structural steels — Technical delivery conditions</i>	Published 1990	BS EN 10025
3.3.5	Ref. Standard 2 of EC3	Dimensions of sections and plates	ENV 1993-1-1	Table 7 of NAD of DD ENV 1993-1-1:1992
3.4	EN 10113	<i>Hot rolled products in weldable fine grain structural steels</i>	1992	BS EN 10113
3.4	prEN 10147	<i>Continuous hot-dip zinc coated non-alloy structural steel sheet and strip: technical delivery conditions</i>	Draft	BS 2989
3.4	ISO 4997	<i>Cold reduced steel sheet of structural quality</i>	1978	—
3.4.1 3) ENV note	“European Technical Approvals or National Documents”	Tolerances on embossments for profiled steel sheeting	None	—

Table 5 — References in EC4-1.1 to other codes and standards

Reference in EC4-1.1	Document referred to	Document title or subject area	Status	UK document
3.4.5	ISO 4998	<i>Continuous hot-dip zinc coated carbon steel sheet of structural quality</i>	1977	—
3.5.2 5) ENV note 3.5.2 6)	“European Standards or European Technical Approvals”	Testing of shear connector material	None	3.4 of BS 5950-3.1:1990
4.3.1 10)	Eurocode 4	Part 1.2 <i>Fire resistance</i>	Draft	BS 5950-8
4.6.2 k)	Euronorm 19-57	<i>IPE joists — Parallel flanged joists</i>	Published 1957	—
4.6.2 k)	Euronorm 53-62	<i>Broad flanged beams with parallel sides</i>	Published 1962	—
4.8.2.2 12)	“appropriate parts of Eurocode 2”	<i>Design of concrete structures</i> Part 1 <i>General rules and rules for buildings</i>	ENV 1992-1-1	DD ENV 1992-1-1 (See note 3)
		Part 1B <i>Precast concrete structures</i>	Draft	BS 8110-1 (See note 3)
4.8.2.5 1)	Eurocode 4	Part 1.2 <i>Fire resistance</i>	Draft	BS 5950-8 BS 8110-1 Section 4 of BS 8110-2:1985
4.8.3.3 1)	“appropriate part of Eurocode 2”	<i>Design of concrete structures</i> Part 1 <i>General rules and rules for buildings</i>	ENV 1992-1-1	DD ENV 1992-1-1 (See note 3)
		Part 1B <i>Precast concrete structures</i>	Draft	BS 8110-1 (See note 3)
4.9.4.1 1)	“relevant Eurocode”	Eurocode 2 <i>Design of concrete structures</i>	Various	(See note 4)
		Eurocode 3 <i>Design of steel structures</i>	Various	(See note 5)
		Eurocode 5 <i>Design of timber structures</i>	In preparation	BS 5268
		Eurocode 6 <i>Design of masonry structures</i>	In preparation	BS 5628
6.1.1 9)	“European Standards or European Technical Approvals or national documents”	Methods of interconnection, other than the shear connectors covered in chapter 6	None	BS 5400-5 BS 5950-3.1
6.3.2.1 ENV note	“Reference Standards”	Minimum dimensions for normal weld collar	Work not started	In the absence of a European and a UK standard DIN 32500-3 and DIN 8563-10 may be used
		Specifications for welding for stud shear connectors		Appendix A of BS 5950-3.1:1990
7.1.1 1)	“another Eurocode”	Eurocode 8 <i>Design of structures for earthquake resistance</i>	In preparation	—
7.1.1 3)	Eurocode 3	Part 1.3 <i>Cold formed thin gauge members and sheeting</i>	Draft	BS 5950-9 (See note 6)
7.2.3 1) 7.4.1 2) 7.5.1 7.5.2 1)	Eurocode 3	Part 1.3 <i>Cold formed thin gauge members and sheeting</i>	Draft	BS 5950-4
7.3.2.1 1)	Eurocode 1	<i>Basis of design and actions on structures</i>	In preparation	2.2 of BS 5950-4:1993

Table 5 — References in EC4-1.1 to other codes and standards

Reference in EC4-1.1	Document referred to	Document title or subject area	Status	UK document
7.4.1 2)	Eurocode 3	Part 1.3 <i>Cold formed thin gauge members and sheeting</i>	Draft	A.2.3 of BS 5950-3.1:1990
8.1 2)	“relevant chapters of Eurocode 2”	Eurocode 2 <i>Design of concrete structures</i>	Various	BS 8110-1 (See note 3)
8.3 2)	“appropriate part of Eurocode 2”			
8.2 2) ENV note	Eurocode 1	<i>Basis of design and actions on structures</i>	In preparation	Section 4 of BS 5975:1982
8.4	Eurocode 2	Part 1B <i>Precast concrete structures</i>	Draft	Section 5 of BS 8110-1:1985
9.1 4) ENV note	“Reference Standards or other Documents”	Responsibility or other requirements to the contractor	—	Contractor’s obligations stated in contract documents, particularly drawings, specification, bill of quantities and standard forms of contract (e.g. ICE Conditions of contract, JCT Standard form of building contract, General conditions of government contract for building and civil engineering works). BS 5975
9.4.3.1 1)	“appropriate standards”	Welding tests	—	A.3 of BS 5950-3.1:1990
9.4.4.1 2)	Eurocode 3	Part 1.3 <i>Cold formed thin gauge members and sheeting</i>	Draft	4.8 of BS 5950-4:1993 Section 6 of BS 5950-6 (See note 6)
10.2.5 2)	Eurocode 3	Part 1.1: Annex Z	Draft	5.3.2.4 of BS 5400-5:1979
A.2.1	DP 9690 ENV 206 EN 10080	<i>Classification of environmental conditions for concrete structures</i> <i>Concrete — Performance, production, placing and compliance criteria</i> <i>Steel for the reinforcement of concrete</i>	In preparation Expected before EC4 Draft	DD ENV 1992-1-1 BS 4449 BS 4482 BS 4483
A.4	ISO 3898 ISO 8930	<i>Bases for design of structures — Notations — General symbols</i> <i>General principles on reliability of structures — List of equivalent terms</i>	1987 1987	— —
NOTE 1 Clause 1.1.1 of Eurocode 4-1.1 is not specific to this Part only, and the reference in 1.1.1 3) to Eurocodes 2 and 3 is a general one. The Parts of these Eurocodes already published or currently in preparation are listed. For those Parts in preparation, Table 5 lists the equivalent UK documents relevant to execution of a building or civil engineering works. NOTE 2 UK documents relevant to Parts 2 of Eurocodes 2 and 3 are not the subject of this NAD. NOTE 3 Part 1.1 of Eurocode 2 and the associated NAD do not deal with considerations special to precast concrete elements. Reference should be made to BS 8110. NOTE 4 For Parts of Eurocode 2 and the equivalent UK documents, see entries in Table 5 for EC4 reference 2.2.1.1 4). NOTE 5 For Parts of Eurocode 3 and the equivalent UK documents, see entries in Table 5 for EC4 reference 2.2.1.1 4). NOTE 6 To be published.				

6 Additional recommendations

6.1 Guidance on EC4-1.1

NOTE 6.1.1 to 6.1.7 should be followed when designing in accordance with EC4-1.1.

6.1.1 Chapter 2. Basis of Design

a) Clause 2.1 2)

Structural integrity. Design rules to provide structural integrity by limiting the effects of accidental damage are given in Annex A.

b) Clause 2.2.1.2 2)

Strength and stability should be checked for the construction stage where the steel beam acts non-compositely to support the permanent load of formwork and the imposed load of fresh concrete plus construction loads or temporary storage loads.

c) Clause 2.3.2.2

Accidental design situation. When designing for the accidental situation in Table 2.1 of EC4-1.1 the values of Ψ_1 , Ψ_2 and A_k should be determined from Annex A and Table 3 of this NAD.

The accidental load A_k (34 kN/m² see A.4) should be multiplied by a γ_A factor of 1.05.

The γ_{GA} factor should be taken as 1.05, except where the dead load is considered as consisting of unfavourable and favourable parts, in which case the favourable part should be multiplied by a γ_{GA} factor of 0.9 and the unfavourable part should be multiplied by a γ_{GA} factor of 1.05.

6.1.2 Chapter 3. Materials

a) Clause 3.2

Pending the issue of prEN 10080 as an EN, reference should be made to BS 4449:1988 (bars) and BS 4483:1985 (welded fabric) for the material properties of reinforcing steels.

The differences between the British Standards and the draft European Standard are summarized in 6.3 a) of the NAD to DD ENV 1992-1-1:1992 (EC2-1).

b) Clause 3.3

For material properties of structural steels to be used in design calculations for composite steel and concrete structures reference should be made to clauses 5 and 6 of the NAD to DD ENV 1993-1-1:1992 (EC3-1.1).

c) Clause 3.4

For additional guidance on the material properties of profiled steel sheeting for composite slabs reference should be made to the NAD to EC3-1.3¹⁾.

d) Clause 3.5.2 6)

The material properties of shear connectors should be in accordance with the recommendations in 3.4 of BS 5950-3.1:1990.

6.1.3 Chapter 4. Ultimate limit state

a) Clause 4.6.3 4)

When calculating the elastic critical moment M_{cr} , from Annex F of EC3-1.1 the additional recommendations give in 6.1.3 e) of the NAD to DD ENV 1993-1-1:1992 (EC3-1.1) apply.

b) Clause 4.7.1

Diagonal, tension and torsional stiffeners should be designed using the method given in 6.1.3 g) of the NAD to DD ENV 1993-1-1:1992 (EC3-1.1).

c) Clause 4.8.2.5 2)

When determining the cover to reinforcement the additional recommendations given in 6.4 a) and b) of the NAD to DD ENV 1992-1-1:1992 (EC2-1) apply.

d) Clause 4.8.3.6

Where no guidance on the buckling length is given in DD ENV 1993-1.1 (EC3-1.1) the nominal effective lengths for a strut given in 4.7.2 of BS 5950-1:1990 should be used.

¹⁾ In preparation.

When calculating the elastic critical load, N_{cr} , a buckling length, l , of less than 0.7 times the system length, L , may be used for a member only where it can be demonstrated that the stiffness of the connecting members and of the connections to be used would justify such a value. In all other cases the buckling length, l , should not be taken as less than 0.7 times the system length.

e) **Clause 4.8.3.9**

For members subject to combined compression and bending the ratio χ_n should be determined as follows.

- 1) Encased steel sections (including web filled sections) and rectangular filled sections

Provided that the non-dimensional slenderness, λ , does not exceed 1.0, the ratio χ_n may be determined from the recommendations given in 4.8.3.13 4) of EC4-1.1. For values of λ in the range 1.0 to 2.0, χ_n should be taken as zero.

- 2) Concrete filled circular and square sections

For concrete filled circular and square sections the ratio χ_n may be determined from the recommendations given in 4.8.3.13 4) of EC4-1.1.

f) **Clause 4.8.3.1 3) c)**

The term “relative slenderness” in the heading of 4.8.3.7 has the same meaning as “non-dimensional slenderness”.

g) **Clause 4.8.3.11**

The design moment resistance in combined compression and uniaxial bending should not exceed the design plastic moment, $M_{pl,Rd}$, irrespective of the normal force N .

h) **Clause 4.8.3.13**

The additional recommendations given in 6.2.3 g) of this NAD supplement the recommendations given in paragraph 6) and supersede those given in paragraph 7) of 4.8.3.13 of EC4-1.1

i) **Clause 4.9.2.2**

The recommendations given in Annex B of this NAD may be used for the design of columns in simple framing. As an alternative to the recommendations given in Annex B, cased columns may be designed using the method given in 6.3.2 of this NAD.

6.1.4 Chapter 6. Shear connection in beams for buildings

a) **Clause 6.3.2.1**

The design shear resistance, P_{Rd} , of shear connectors in lightweight concrete with a dry density exceeding 1 750 kg/m³ should be taken as 90 % of the value of the design shear resistance calculated for normal weight concrete with the same characteristic strength.

b) **Clause 6.4.1.2**

When calculating the cover required for shear connectors, the specified cover for reinforcement should be in accordance with Table 6 of the NAD to 1992-1-1:1992 (EC2-1).

c) **Clause 6.5.2.1 1)**

The design pre-loading force, $F_{p,Cd}$, used in design calculations should be determined in accordance with the recommendations given in 6.1.4 d) of the NAD to 1993-1-1:1992.

d) **Clause 6.5.2.1 2)**

If after final tightening, the bolt or nut of a high strength friction grip bolt assembly installed in accordance with the recommendations given in BS 4604 is slackened off for any reason the bolt, nut and washer (washers) should be discarded and not re-used.

6.1.5 Chapter 7. Composite slabs with profiled steel sheeting for buildings

a) **Clause 7.3.2.1**

The recommendations on construction loads given in 2.2.3 of BS 5950-4:1993 supersede paragraphs 2) and 3) of 7.3.2.1 in EC4-1.1.

b) **Clause 7.3.2.1 4)**

When the central deflection, δ , of the profiled steel sheeting during construction exceeds either 1/250 or 20 mm the additional weight of concrete due to the deflection of the sheeting should be taken into account in the self-weight of the concrete slab and in the design of the supporting structure.

c) *Clause 7.4.1*

As an alternative to elastic analysis, profiled steel sheeting may be analysed in accordance with the recommendations given in EC3-1.3²⁾.

d) *Clause 7.4.1 2)*

Profiled steel sheeting spanning onto a steel beam may be assumed to provide restraint to the beam flanges to which it is connected and should be fixed using either:

- shot fired fixings;
- self tapping screws;
- welding (including stud shear connectors welded through the sheeting); or
- bolting.

The spacing of fasteners should not be greater than 500 mm at the ends of sheets, nor greater than 1 000 mm where the sheet is continuous.

The design of the fixings should be in accordance with BS 5950-6²⁾.

The stiffness of other types of shuttering or formwork is generally not sufficient to provide the necessary lateral restraint, unless specifically designed to do so.

6.1.6 Annex C. Simplified calculation method for resistance of doubly symmetric composite cross sections in combined compression and bending

a) *Clauses C.1 and C.4*

The design moment of resistance in combined compression and uniaxial bending should not exceed the design plastic resistance, $M_{pl,Rd}$, irrespective of the normal force N .

6.1.7 Annex D. Design of composite columns with mono-symmetrical cross sections — simplified method

a) *Clause D.4*

The design moment of resistance in combined compression and uniaxial bending should not exceed in magnitude the appropriate design plastic resistance moment $M_{pl,y-,Rd}$ or $M_{pl,y+,Rd}$, irrespective of the normal force N .

6.2 Recommendations on subjects not covered in EC4-1.1

6.2.1 Fire Resistance

Pending the issue of ENV 1994-1-2 (EC4-1.2), BS 5950-8:1990 should be used.

6.2.2 Cased Sections

As an alternative to the rules given in Annex B of this NAD, cased columns and beams may be designed using the method given in **6.2.3** of the NAD to DD ENV 1993-1-1:1992 (EC3-1.1).

6.2.3 Vibration

Where it is necessary to control vibration, the recommendations given in **6.4** of BS 5950-3.1:1990 should be used.

²⁾ In preparation.

Annex A (normative)

General recommendations for structural integrity

A.1 Introduction

All structures should follow the principles given in **2.1** of EC4-1.1. This annex gives application rules which satisfy the principle of structural integrity given in **2.1 2)** of EC4-1.1. These application rules apply to buildings.

For the purposes of this provision, it may be assumed that substantial permanent deformation of members and their connections is acceptable.

A.2 Tying forces

A.2.1 Recommendations for all buildings

Every building should be effectively tied together at each principal floor and roof level. All columns should be effectively restrained in two directions approximately at right angles at each principal floor or roof which they support.

This anchorage may be provided by either beams or tie members. Where possible these should be arranged in continuous lines as close as practicable to the columns and to each edge. At re-entrant corners the peripheral tie should be anchored into the framework.

Ties may be either steel members or steel reinforcement embedded in concrete or masonry provided that they are properly anchored to the framework.

Steel members and reinforcement provided for other purposes may be utilized as ties. When checked as ties other loading may be ignored. Beams designed to carry the floor or roof loading will generally be suitable provided that their end connections are capable of resisting tension.

All ties and their end connections should be of a standard of robustness commensurate with the structure of which they form a part and should have a design tension resistance of not less than 75 kN at floors or 40 kN at roof level.

Ties are not required at a roof level where steelwork supports cladding weighing not more than 0.7 kN/m² and carries roof loads only.

Where a building is provided with expansion joints, each section between expansion joints should be treated as a separate building for the purpose of this clause.

A.2.2 Additional recommendations for tall multi-storey buildings

Local or national regulations may stipulate that tall multi-storey buildings be designed to localize accidental damage.

Composite steel-concrete framed buildings which satisfy the recommendations of **A.2.1** may be assumed to meet this requirement provided that the five additional conditions given below are met.

A tall multi-storey building which is required to be designed to localize accidental damage but which does not satisfy these five additional conditions should be checked as recommended in **A.3**.

- a) *Bracing*. The bracing or shear walls should be so distributed throughout the building that no substantial portion of the structural framework is solely reliant on a single plane of bracing in each direction.
- b) *Tying*. The ties referred to in **A.2.1** should be arranged in continuous lines wherever practicable throughout each floor and roof level in two directions approximately at right angles. These and their connections should be checked for the following design tensile forces, which need not be considered as additive to other forces.

- 1) Generally: $0.5w_f s_t L_a$ for any internal ties and $0.25w_f s_t L_a$ for edge ties but not less than 75 kN for floors or 40 kN at roof level,

where

w_f is the total factored dead and imposed load per unit area of floor or roof;

s_t is the mean transverse spacing of the ties;

L_a is the greatest distance, in the direction of the tie under consideration, between the centres of adjacent lines of supporting columns, frames or walls.

2) At the periphery: ties anchoring columns at the periphery of a floor or roof should be checked for the greater of:

- the force given in item b) 1) and
- 1 % of the design vertical load in the column at that level.

c) *Columns*. All column splices should be capable of resisting a design tensile force of not less than two-thirds of the design vertical load applied to the column from the floor level next below the splice.

Where the framework is not of continuous construction in at least one direction, the columns should be carried through at each beam-to-column connection.

d) *Integrity*. Any beam which carries a column should be checked, together with the members which support it, for localization of damage as recommended in **A.3**.

e) *Floor units*. Where precast concrete or other heavy floor or roof units are used they should be effectively anchored in the direction of their span either to each other over a support or directly to their supports as recommended in BS 8110.

A.3 Localization of damage

At the accidental limit state, where required by **A.2**, the effect of the removal of any single column, or beam carrying a column should be assessed for each storey of a building in turn. Where the removal of one of these members would result in collapse of any area greater than 70 m² or 15 % of the area of the storey, that member should be designed as a key element as recommended in **A.4**.

In this check the appropriate value of Ψ of the ordinary wind load and of the ordinary imposed load should be considered together with the dead load, except that in the case of buildings used predominantly for storage, or where the imposed load is of a persistent nature, the full imposed load should be used. The combination factors, Ψ_1 and Ψ_2 , for accidental design situations are given in Table 3. The γ_{GA} factor should be taken as 1.05, except that where the dead load is considered as consisting of unfavourable and favourable parts, the favourable part should be multiplied by a γ_{GA} factor of 0.9 and the unfavourable part should be multiplied by a γ_{GA} factor of 1.05.

A.4 Design of key elements

Key elements or members are single structural elements which support a floor or roof area of more than 70 m² or 15 % of the area of the storey.

Any other member or other structural component which provides lateral restraint vital to the stability of a key element should itself also be designed as a key element for the same accidental loading.

Where it is required by **A.3** to design a member as a key element, the accidental loading, A_k , should be chosen having particular regard to the importance of the key element and the consequences of failure and should not be less than 34 kN/m². The accidental load, A_k , should be multiplied by a γ_A factor of 1.05.

Accidental loads should be applied to members from appropriate directions together with the reactions from other building components attached to the member which are subject to the same loading but limited to the ultimate resistance of these components or their connections.

When designing for the accidental situation the member should be designed for the accidental load in combination with the dead and imposed loads [see **2.3.2.2** 2) of EC4-1.1]. The combination factors for use with these loads are given in Table 3.

Annex B (normative)

Application rules for composite columns in simple framing

B.1 General

The application rules in **B.2** to **B.5** apply to columns in structures of simple framing, and are intended to be used in conjunction with the method given in **4.8.3** of EC4-1.1.

B.2 Pattern loading

Pattern loading need not normally be considered in simple framing. However, unbalanced loading due to variations in span or specified loading should be taken into account.

B.3 Buckling length of column

The buckling length of a composite column should be taken as the system length. When the nominal moments obtained as described in **B.5** are the only applied moments, the moment ratio, r , should be taken as 1.0 giving a moment factor β of 1.1 in **4.8.3.10** 4) of EC4-1.1 and a ratio χ_n of 0 in **4.8.3.13** 4) of EC4-1.1.

B.4 Eccentricities

Beam end reactions should be taken as acting at a distance from the face of the composite section equal to 100 mm, or at the centre of the length of stiff bearing, whichever gives the great eccentricity.

B.5 Unbalanced loading

Where composite columns are subject to unbalanced loading, they should be designed for the resulting moment. In multi-storey buildings where the columns are effectively continuous at each floor level, the net moment at one level should be divided between the column lengths above and below that level in proportion to the values of (EI/L) , for each length. The value of EI for a composite column should be determined according to 4.9.6.2 of EC4-1.1.

The moments due to the eccentricities given in B.4 should be assumed to have no effect at the levels above and below the level at which they are applied.

B.6 Connections

Connections are to be designed as non-composite in accordance with the rules given in clause 6 of DD ENV 1993-1-1:1992 (EC3-1.1), ignoring any reinforcement which may be provided for the control of cracking. The connections should satisfy the requirements of 6.4.2.1 and 6.4.3.1 of DD ENV 1993-1-1:1992 (EC3-1.1) for nominally pinned connections.

List of references (see clause 2)

Normative references

BSI publications

BRITISH STANDARDS INSTITUTION, London

- BS 648:1964, *Schedule of weights of building materials*.
- BS 4604, *Specification for the use of high strength friction grip bolts in structural steelwork*.
- BS 4604, *Metric series*.
- BS 4604-1:1970, *General grade*.
- BS 4604-2:1970, *Higher grade (parallel shank)*.
- BS 5950, *Structural use of steelwork in building*.
- BS 5950-3, *Design of composite construction*.
- BS 5950-3.1:1990, *Code of practice for design of simple and continuous composite beams*.
- BS 5950-4:1993, *Code of practice for design of composite slabs with profiled steel sheeting*.
- BS 5950-6, *Code of practice for design of light gauge sheeting, decking and cladding*³⁾.
- BS 5950-8:1990, *Code of practice for fire resistant design*.
- BS 5975:1982, *Code of practice for falsework*.
- BS 6399, *Design loading for buildings*.
- BS 6399-1:1984, *Code of practice for dead and imposed loads*.
- BS 6399-3:1988, *Code of practice for imposed roof loads*.
- BS 8110, *Structural use of concrete*.
- BS 8110-1:1985, *Code of practice for design and construction*.
- BS 8110-2:1985, *Code of practice for special circumstances*.
- CP3, *Code of basic data for the design of buildings*.
- CP3:Chapter V, *Loading*.
- CP3:Chapter V-2:1972, *Wind loads*.
- DD ENV 1992, *Eurocode 2: Design of concrete structures*.
- DD ENV 1992-1-1:1992, *General rules and rules for buildings (together with United Kingdom National Application Document)*.
- DD ENV 1993, *Eurocode 3: Design of steel structures*.
- DD ENV 1993-1-1:1992, *General rules and rules for buildings (together with United Kingdom National Application Document)*.

Informative references

BSI publications

BRITISH STANDARDS INSTITUTION, London

- BS 2989:1992, *Specification for continuously hot-dip zinc coated and iron-zinc alloy coated steel flat products: tolerances on dimensions and shape*.
- BS 4449:1988, *Specification for carbon steel bars for the reinforcement of concrete*.
- BS 4482:1985, *Specification for cold reduced steel wire for the reinforcement of concrete*.
- BS 4483:1985, *Specification of steel fabric for the reinforcement of concrete*.
- BS 5268, *Structural use of timber*.
- BS 5400, *Steel, concrete and composite bridges*.

³⁾ In preparation

BS 5400-5:1979, *Code of practice for design of composite bridges*.
BS 5628, *Code of practice for use of masonry*.
BS 5950, *Structural use of steelwork in building*.
BS 5950-5:1987, *Code of practice for design of cold formed sections*.
BS 5950-7:1992, *Specification for materials and workmanship: cold formed sections*.
BS EN 10025:1993, *Hot rolled products of non-alloy structural steels — Technical delivery conditions*.
BS EN 10113, *Hot-rolled products in weldable fine grain structural steels*.
BS EN 10113-1:1993, *General delivery conditions*.
BS EN 10113-2:1993, *Delivery conditions for normalized/normalized rolled steels*.
BS EN 10113-3:1993, *Delivery conditions for thermomechanical rolled steels*.

ISO publications

International Organization for Standardization, (ISO), Geneva (All publications are available from BSI Sales)

ISO 1000:1981, *SI units and recommendations for the use of their multiples and of certain other units*.
ISO 3898:1987, *Bases for design of structures — Notations — General symbols*.
ISO 4997:1991, *Cold-reduced steel sheet of structural quality*.
ISO 4998:1991, *Continuous hot-dip zinc-coated carbon steel sheet of structural quality*.
ISO 6707-1:1989, *Building and civil engineering — Vocabulary — Part 1: General terms*.
ISO 8930:1987, *General principles on reliability for structures — List of equivalent terms*.

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English version

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

Conception et dimensionnement des
structures mixtes acier-béton —
Partie 1-1: Règles générales et règles pour les
bâtiments

Entwurf von Verbundbauwerken aus Stahl
und Beton — Teil 1-1: Allgemeine Regeln und
Regeln für Hochbauten

This European Prestandard was approved by CEN on 1992-10-23 as a prospective standard for provisional application. The period of validity of this ENV is limited initially to three years. After two years the members of CEN will be requested to submit their comments, particularly on the question whether the ENV can be converted into a European Standard (EN).

CEN members are required to announce the existence of this ENV in the same way as for an EN and to make the ENV available promptly at national level in an appropriate form. It is permissible to keep conflicting national standards in force (in parallel to the ENV) until the final decision about the possible conversion of the ENV into an EN is reached.

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CEN

European Committee for Standardization
Comité Européen de Normalisation
Europäisches Komitee für Normung

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Foreword to Eurocode 4: Part 1.1

0.1 Objectives of the Eurocodes

- 1) The structural Eurocodes comprise a group of standards for the structural and geotechnical design of buildings and civil engineering works.
- 2) They are intended to serve as reference documents for the following purposes:
 - a) As a means to prove compliance of building and civil engineering works with the essential requirements of the Construction Products Directive (CPD).
 - b) As a framework for drawing up harmonized technical specifications for construction products.
- 3) They cover execution and control only to the extent that is necessary to indicate the quality of the construction products, and the standard of the workmanship, needed to comply with the assumptions of the design rules.
- 4) Until the necessary set of harmonized technical specifications for products and for methods of testing their performance is available, some of the Structural Eurocodes cover some of these aspects in informative annexes.

0.2 Background to the Eurocode programme

- 1) The Commission of the European Communities (CEC) initiated the work of establishing a set of harmonized technical rules for the design of building and civil engineering works which would initially serve as an alternative to the different rules in force in the various Member States and would ultimately replace them. These technical rules became known as the "Structural Eurocodes".
- 2) In 1990, after consulting their respective Member States, the CEC transferred work of further development, issue and updates of the Structural Eurocodes to CEN, and the EFTA Secretariat agreed to support the CEN work.
- 3) CEN Technical Committee CEN/TC 250 is responsible for all Structural Eurocodes.

0.3 Eurocode programme

- 1) Work is in hand on the following Structural Eurocodes, each generally consisting of a number of parts:

EN 1991, Eurocode 1: Basis of design and 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.

In addition the following may be added to the programme:

EN 1999, Eurocode 9: Design of aluminium structures.

2) Separate sub-committees have been formed by CEN/TC 250 for the various Eurocodes listed above.

3) This part of the Structural Eurocode for Design of Composite Steel and Concrete Structures is being issued by CEN as a European Prestandard (ENV) with an initial life of three years.

4) This Prestandard is intended for experimental practical application in the design of the building and civil engineering works covered by the scope as given in 1.1.2, and for the submission of comments.

5) After approximately two years CEN members will be invited to submit formal comments to be taken into account in determining future action.

6) Meanwhile, feedback and comments on this Prestandard should be sent to the Secretariat of sub-committee CEN/TC 250/SC 4 at the following address:

National Standards Authority of Ireland,
Glasnevin, Dublin 9, Ireland

or to your national standards organization.

0.4 National Application Documents

1) In view of the responsibilities of authorities in member countries for the safety, health and other matters covered by the essential requirements of the CPD, certain safety elements in this ENV have been assigned indicative values which are identified by . The authorities in each member country are expected to assign definitive values to these safety elements.

2) Many of the harmonized supporting standards, including the Eurocodes giving values for actions to be taken into account and measures required for fire protection, will not be available by the time this Prestandard is issued. It is therefore anticipated that a National Application Document (NAD) giving definitive values for safety elements, referencing compatible supporting standards and providing national guidance on the application of this Prestandard, will be issued by each member country or its Standard Organization.

3) It is intended that this Prestandard is used in conjunction with the NAD valid in the country where the building or civil engineering works are located.

0.5 Matters specific to this Prestandard

0.5.1 Cross-references to other Eurocodes

1) It is stated in 1.1.2 5) that “Part 1.1 of Eurocode 4 shall in all cases be used in conjunction with Parts 1.1 of Eurocodes 2 and 3”. To assist users, many cross-references to Eurocode 2 and 3 are given, in the general form “clause ... of EC2” (or EC3). In this Prestandard:

- EC2 means ENV 1992-1-1 Eurocode 2: Part 1.1; revised final draft, 31 October 1990;
- EC3 means ENV 1993-1-1 Eurocode 3: Part 1.1; edited draft, issue 5, November 1990, corrected July 1991.

[Drafting note: These definitions of EC2 and EC3 are subject to revision by CEN, to enable reference to be made to the published ENV versions of EC2 and EC3.]

It should not be assumed that cross-references are given to all relevant clauses of EC2 and EC3.

2) Repetitions from EC2 and EC3 are limited to material that is frequently needed for reference; for example, Table 3.1 on properties of concrete.

3) There are general references to Eurocode 1, but no references to specific clauses. In a few clauses (e.g., 7.3.2.1) application rules for actions are given. These apply only until the relevant Part of Eurocode 1 is available.

0.5.2 The treatment of γ_M for structural steel

The use in this Prestandard of partial safety factors for concrete and reinforcement is as in EC2. For structural steel, clause 0.5.5 of EC3 is relevant. It was not possible to reproduce the method of EC3, where factors γ_{M0} or γ_{M1} are applied to resistances of cross-sections or members, because most of the γ_M factors given in this Prestandard are applied to strengths of materials (clause 2.2.3.2). The symbols γ_{M0} and γ_{M1} are therefore replaced in Eurocode 4: Part 1.1 by different symbols, γ_a and γ_{Rd} respectively. The method of drafting makes possible the assignment by a national authority of definitive values such that $\gamma_a \neq \gamma_{Rd}$. In this respect, it is consistent with the use of factors γ_{M0} and γ_{M1} in EC3.

0.5.3 Notes in this Prestandard

Two types of note are used:

- [Note: ...]. These notes should appear also in the EN version of Eurocode 4: Part 1.1.
- [ENV Note: ...]. These notes relate to other Eurocodes and Reference Standards as they are in mid-1991. They will not appear in this form in the EN version of Eurocode 4: Part 1.1.

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1 Introduction

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. The composite structures and members are made of structural steel and reinforced or prestressed concrete connected together to resist loads. Eurocode 4 is subdivided into various separate parts, see 1.1.2 and 1.1.3.

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

3) Execution⁴⁾ is covered in Chapter 9, and by reference to Eurocodes 2 and 3, to the extent that it is necessary to indicate the quality of the construction materials and products which should be used and the standard of workmanship on site needed to comply with the assumptions of the design rules. Generally, the rules related to execution and workmanship are to be considered as minimum requirements which may have to be further developed for particular types of buildings or civil engineering works⁴⁾ and methods of construction⁴⁾.

[ENV Note: See also the Foreword; in the present document, execution is not covered in Chapter 9 to the extent stated above.]

4) Eurocode 4 does not cover the special requirements of seismic design. Provisions related to such requirements are provided in Eurocode 8 “Design of structures for earthquake resistance”⁵⁾ which complements or adapts the rules of Eurocode 4 specifically for this purpose.

5) Numerical values of the actions on buildings and civil engineering works to be taken into account in the design are not given in Eurocode 4. They are given in Eurocode 1 “Basis of design and actions on structures”⁵⁾ applicable to the various types of construction⁴⁾.

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 and members for buildings and civil engineering works.

2) In addition, Part 1.1 gives for composite slabs, beams, columns and frames detailed rules which are mainly applicable to ordinary buildings. The applicability of these rules may be limited, for practical reasons or due to simplifications; their use and any limits of applicability are explained in the text where necessary.

3) The following subjects are dealt with in Part 1.1:

- Chapter 1: Introduction
- Chapter 2: Basis of Design
- Chapter 3: Materials
- Chapter 4: Ultimate limit states
- Chapter 5: Serviceability limit states
- Chapter 6: Shear connection in beams for buildings
- Chapter 7: Composite slabs with profiled steel sheeting for buildings
- Chapter 8: Floors with precast concrete slabs for buildings
- Chapter 9: Execution
- Chapter 10: Design assisted by testing
- Annex A: Reference documents (Normative)
- Annex B: Lateral-torsional buckling (Normative)
- Annex C: Resistance of doubly symmetric composite cross sections in combined compression and bending (Normative)
- Annex D: Composite columns with mono-symmetrical cross section (Normative)
- Annex E: Partial shear connection method for composite slabs (Normative)
- Annex F: Checklists of the information required in test reports (Informative)

⁴⁾ For the meaning of this term, see 1.4.1 2)

⁵⁾ At present at the draft stage.

- 4) Chapter 1 and Chapter 2 are common to all Eurocodes, with the exception of some additional clauses which are required for composite construction.
- 5) Part 1.1 of Eurocode 4 shall in all cases be used in conjunction with Parts 1.1 of Eurocodes 2 and 3.
- 6) This Part 1.1 does not cover:
 - resistance to fire nor, more generally, resistance at non-climatic temperatures
 - resistance to highly repeated actions liable to result in fatigue
 - resistance to dynamic actions that are not quasi-static
 - particular aspects of special types of civil engineering works (such as bridges, crane girders, masts, towers, offshore platforms, nuclear containment vessels); see 1.1.3 2)
 - particular aspects of special types of buildings (such as industrial buildings as far as fatigue would need to be considered)
 - prestressed structures
 - members the structural steel component of which has cross-sections with no axis of symmetry parallel to the plane of its web
 - members the structural concrete component of which is made of no-fines concrete, or of aerated concrete or of concrete including heavy aggregate, or has less reinforcement than the minimum values given in clause 5.4 of EC2, or contains expanding or non-shrinkage admixtures
 - composite plates consisting of a flat steel plate connected with a concrete slab
 - sway frames
 - some types of shear connectors (see Chapter 6)
 - semi-continuous frames such that rigid-plastic global analysis cannot be used [see 1.4.2 1), and in EC3 clause 5.2.2.4 and Table 5.2.1]
 - base plates beneath composite columns
 - particular aspects of composite piles for foundations
 - particular aspects of members with haunched or tapered steel components
 - particular aspects of box girders
 - particular aspects of totally or partially encased beams (see however 4.3.3.1 and Annex B)
 - and more generally particular aspects mentioned as not covered in the following chapters (relating for example to the form of cross-sections).
- 7) The implicit inclusion of a type of building or a form of structure [as defined in 1.4.1 2)] does not imply that all details of its design are covered conclusively.

1.1.3 Further Parts of Eurocode 4

- 1) This Part 1.1 of Eurocode 4 will be supplemented by further Parts which will complement or adapt it for particular aspect of special types of buildings and civil engineering works, special methods of construction and certain other aspects of design which are of general practical importance.
- 2) Further Parts of Eurocode 4 which, at present, are being prepared or are planned are the following: Part 1.2 Fire resistance; Part 2 Bridges.

1.2 Distinction between principles and application rules

- 1) Depending on the character of the individual clauses, distinction is made in this Eurocode between Principles and Application Rules.
- 2) The Principles comprise:
 - general statements and definitions for which there is no alternative, as well as
 - requirements and analytical models for which no alternative is permitted unless specifically stated.
- 3) *The Principles are printed in roman type.*
- 4) The Application Rules are generally recognised rules which follow the Principles and satisfy their requirements.

5) It is permissible to use alternative design rules different from the Application Rules given in the Eurocode, provided that it is shown that the alternative rules accord with the relevant Principles and are at least equivalent with regard to the resistance, serviceability and durability achieved by the structure if designed using the present Eurocode.

6) *The Application Rules are printed in italics. This is an Application Rule.*

[Note: Tables and figures have the same status as the paragraphs to which they relate.]

1.3 Assumptions

- 1) The assumptions given in clauses 1.3 1) of EC2 and EC3, which are identical, are applicable.
- 2) The design procedures are valid only when the requirements for execution workmanship given in Chapter 9 are also complied with.
- 3) Numerical values identified by are given as indications. Other values may be specified by Member States.

1.4 Definitions

1.4.1 Terms common to all Structural Eurocodes

- 1) Unless otherwise stated in the following, the terminology used in International Standard ISO 8930 applies.
- 2) The following terms are used in common for all Structural Eurocodes with the following meanings.
 - **Construction Works:** Everything that is constructed or results from construction operations⁶⁾. This term covers both building and civil engineering works. It refers to the complete construction comprising both structural and non-structural elements.
 - **Execution:** The activity of creating a building or civil engineering works. The term covers work on site; it may also signify the fabrication of components off site and their subsequent erection on site⁷⁾.
 - **Structure:** Organized combination of connected parts designed to provide some measure of rigidity⁸⁾. This term refers to load carrying parts.
 - **Type of building or civil engineering works:** Type of “construction works” designating its intended purpose, e.g. dwelling house, industrial building, road bridge⁹⁾.
 - **Form of structure:** Structural type designating the arrangement of structural elements, e.g. beam, triangulated structure, arch, suspension bridge.
 - **Construction material:** A material used in construction work, e.g. concrete, steel, timber, masonry.
 - **Type of construction:** Indication of principal structural material, e.g. reinforced concrete construction, steel construction, timber construction, masonry construction, composite construction.
 - **Method of construction:** Manner in which the construction will be carried out, e.g. cast in place, prefabricated, cantilevered.
 - **Structural system:** The load bearing elements of a building or civil engineering works and the way in which these elements are assumed to function, for the purpose of modelling.
- 3) The equivalent terms in various languages are given in Table 1.1.

1.4.2 Special terms used in this Part 1.1 of Eurocode 4

- 1) The following terms are used in Part 1.1 of Eurocode 4 with the following meanings:
 - **Frame:** A structure or portion of a structure, comprising an assembly of directly connected structural members, designed to act together to resist load. This term covers both plane frames and three-dimensional frames.

⁶⁾ This definition accords with International Standard ISO 6707-1.

⁷⁾ (for the English version only): In English “construction” may be used instead of “execution” in certain combinations of words where there is no ambiguity (e.g. “during construction”).

⁸⁾ International Standard ISO 6707-1 gives the same definition but adds “or a construction works having such an arrangement”. In the Structural Eurocodes this addition is not used, in order to facilitate unambiguous translations.

⁹⁾ (for the English version only): “Type of construction works” is not used in English.

Table 1.1 — List of Equivalent Terms in various Languages

ENGLISH	FRANCAIS	DEUTSCH	ITALIANO	NEDERLANDS	ESPAÑOL
Construction Works	Construction	Bauwerk	Costruzione	Bouwwerk	Obras
Execution	Execution	(Bau-) Ausführung	Esecuzione	Uitvoering	Ejecucion
Structure	Structure	Tragwerk	Struttura	Draag-constructie	Estructura
Type of Building or civil engineering works	Nature de construction	Art des Bauwerks	Tipo di costruzione	Type bouwwerk	Tipe de obra
Form of structure	Type de structure	Art des Tragwerks	Tipo di struttura	Type draag-constructie	Tipologia estructural
Construction material	Materiau de construction	Baustoff; Werkstoff (Stahlbau)	Materiale da costruzione	Constructie materiaal	Material de construccion
Type of construction	Mode de construction	Bauweise	Sistema costruttivo	Bouwwijze	Tipo de construccion
Method of construction	Procede d'execution	Bauverfahren	Procedimento esecutivo	Bouwmethode	Procedimiento constructivo
Structural system	Système structural	Tragsystem	Sistema strutturale	Constructief systeem	Sistema estructural

— **Sub-frame:** A frame which forms part of a larger frame, but is treated as an isolated frame in a structural analysis.

— **Type of framing:** Terms used to distinguish between frames which are either.

— continuous, in which only both equilibrium and the structural properties of the members need be considered in the global analysis;

— semi-continuous, in which also the structural properties of the connections need explicit consideration in the global analysis; or

— simple, in which only equilibrium need be considered in the global analysis.

— For sway frames and non-sway frames see 4.9.4.2 and EC3 clause 5.2.5.2.

— For braced frames and non-braced frames see 4.9.4.3 and EC3 clause 5.2.5.3.

— **Composite frame:** In Part 1.1 of EC4, a composite frame is a framed structure for a building or similar construction works, in which some or all of the beams and columns are composite members and most of the remaining members are structural steel members. The use of reinforced or prestressed concrete or masonry members in bracing systems (as defined in EC3) is not excluded.

— **Composite member:** A structural member with components of concrete and of structural or cold-formed steel, interconnected by shear connection so as to limit the longitudinal slip between concrete and steel and the separation of one component from the other.

— **Propped structure or member:** A structure or member the steel elements of which are supported until the concrete elements are able to resist stresses.

— **Unpropped structure or member:** A structure or member in which the weight of concrete elements is applied to steel elements.

— **Shear connection:** An interconnection between the concrete and steel components of a composite member that has sufficient strength and stiffness to enable the two components to be designed as parts of a single structural member.

Except as provided in 4.8.2.7 and 7.1.2.2 shear connection means mechanical shear connection that does not rely on bond or adhesion at interfaces between steel and concrete.

— Full and partial shear connection are defined in 4.1.2 6).

- **Composite connection:** A connection between a composite member and any other member in which reinforcement is intended to contribute to the resistance of the connection.
- **Rigid composite connection:** A composite connection such that its deformation has no significant influence on the distribution of internal forces and moments in the structure, nor on its overall deformation (see 4.10.2.).
- **Composite column:** A composite member subjected mainly to compression and bending. Only columns with cross-sections of the types defined in 4.8.1 are treated in this Eurocode.
- **Composite beam:** A composite member subjected mainly to bending. Only those in which the structural steel section is symmetrical about its minor axis are treated in this Eurocode.
- **Continuous composite beam:** A beam with three or more supports, in which the steel section is either continuous over internal supports or is jointed by full-strength and rigid connections, with connections between the beam and each support such that it can be assumed that the support does not transfer significant bending moment to the beam. At the internal supports the beam may have either effective reinforcement or only nominal reinforcement.
- **Composite slab:** A bi-dimensional horizontal composite member subjected mainly to bending, in which profiled steel sheets:
 - are used as permanent shuttering capable of supporting wet concrete, reinforcement and site loads, and
 - subsequently combine structurally with the hardened concrete and act as part or all of the tensile reinforcement in the finished slab.
- **Global analysis:** The determination of a consistent set of internal force and moments in a structure which are in equilibrium with a particular defined set of actions on the structure, and are based on the properties of the materials.

[ENV Note: The terminology of the various types of analyses has not yet been fully harmonised between EC2, EC3 and EC4.]

1.5 S.I Units

- 1) S.I. Units shall be used in accordance with ISO 1000.
- 2) For calculations, the following units are recommended:
 - forces and loads : kN, kN/m, kN/m²
 - unit mass : kg/m³
 - unit weight : kN/m³
 - stresses and strengths : N/mm² (= MN/m² or MPa)
 - moments (bending) : kNm.

1.6 Symbols used in part 1.1 of Eurocode 4

- 1) Only the main symbols are defined in this chapter. Symbols which are used only in small parts of this Eurocode are defined where they appear.

[Note: The following lists of symbols include the principal combinations of symbols and subscripts used in this Eurocode. The lists do not include symbols used in one place only, nor those symbols used in EC2 and EC3 but not directly in EC4.]

1.6.1 Latin upper case letters

A	Accidental action; Area
C	Fixed value; Factor
E	Effect of actions; Modulus of elasticity
F	Action; Force
G	Permanent action; shear modulus
I	Second moment of area
K	Stiffness factor (I/L)
L	Length; Span; System length

M	Moment in general; Bending moment
M_{Rd}	Design value of the resisting bending moment
M_{Sd}	Design value of the applied internal bending moment
N	Axial force; Number of shear connectors
P_R	Shear resistance of a shear connector
Q	Variable action
R	Resistance
S	Internal forces and moments (with subscripts d or k)
V	Shear force
W	Section modulus
X	Value of a property of a material

1.6.2 Greek upper case letters

Δ	Difference in(precedes main symbol)
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1.6.3 Latin lower case letters

a	Distance; Geometrical data
b	Width; Breadth
c	Distance; Outstand; Thickness of concrete cover
d	Diameter; Depth
e	Eccentricity
f	Strength (of a material)
f_{ck}	Characteristic compressive strength of concrete
f_{sk}	Characteristic tensile yield strength of reinforcement
f_u	Specified ultimate tensile strength of the material of a stud, a bolt, a rivet...
f_y	Nominal tensile yield strength of structural steel
f_{yp}	Characteristic (nominal) tensile yield strength of profiled steel sheeting
h	Height
i	Radius of gyration
k	Coefficient; Factor
l	(or ℓ or L) Length; Span; Buckling length. [Note: l can be replaced by L or by ℓ (handwritten) for certain lengths or to avoid confusion with 1 (numeral).]
m	Factor for composite slabs
n	Modular ratio
r	Radius
s	Spacing; Distance
t	Thickness
v	Shear force per unit length
w	Crack width
xx, yy, zz	Rectangular axes

1.6.4 Greek lower case letters

α	Angle; Ratio; Coefficient of linear thermal expansion; Factor
β	Angle; Ratio; Factor
γ	Partial safety factor (always with appropriate subscript: e.g., F, G, Q, A, M, Ma, a, ap, c, s, v, Rd)
δ	Steel contribution ratio; Deflection
ϵ	Strain; Coefficient
η	Coefficient
θ	Angle; Slope
λ	(or λ if non-dimensional) Slenderness ratio
μ	Coefficient of friction; Moment ratio
ν	Poisson's ratio
ρ	Unit mass; Reinforcement ratio
σ	Normal stress
τ	Shear stress
φ	Diameter of a reinforcing bar
χ	Reduction factor (for buckling)
Ψ	Factors defining representative values of variable actions; Stress ratio

1.6.5 Subscripts

A	Accidental
a	Structural steel
b	Buckling; Bolt; Beam; Bottom
c	Compression; Concrete; Composite cross section
cr	(or crit) Critical
cs	Concrete shrinkage
d	Design
dst	Destabilizing
eff	Effective
e	Effective (with further subscript)
e ℓ	Elastic
f	Flange; Full; Front
G	Permanent (referring to actions)
h	Haunch
i	Index (replacing a numeral)
inf	Inferior; Lower
k	Characteristic
l	(or ℓ) Longitudinal
LT	Lateral — torsional
M	Material
m	Allowing for bending moment; Mean
max	Maximum
N	Allowing for axial force
nom	Nominal
p	(possibly supplementing a) Profiled steel sheeting
p ℓ	Plastic
Q	Variable (referring to actions)
R	Resistance
r	Reduced

S	Internal fore; Internal moment
s	Reinforcing steel
stb	Stabilizing
sup	Superior; Upper
t	Tension; Tensile; Transversal; Top
ten	Tension
u	Ultimate
v	Vertical; Related to shear connection
w	Web
x	Axis along member
y	Major axis of cross-section; Yield
z	Minor axis of cross-section
0,1,2,	etc.... Particular values

1.6.6 Use of subscripts in part 1.1 of Eurocode 4

Reference should be made to clause 1.6.6 of Eurocode 3.

1.6.7 Conventions for member axes

Reference should be made, if relevant, to clause 1.6.7 of Eurocode 3.

2 Basis of design

2.1 Fundamental requirements

- 1) A structure shall be designed and constructed in such a way that:
 - with acceptable probability, it will remain fit for the use for which it is required, having due regard to its intended life and its cost, and
 - with appropriate degrees of reliability, it will sustain all actions and other influences likely to occur during execution and use and have adequate durability in relation to maintenance costs.
- 2) A structure shall also be designed in such a way that it will not be damaged by events like explosions, impact or consequences of human errors, to an extent disproportionate to the original cause.
- 3) *The potential damage should be limited or avoided by appropriate choice of one or more of the following:*
 - *avoiding, eliminating or reducing the hazards which the structure is to sustain*
 - *selecting a structural form which has low sensitivity to the hazards considered*
 - *selecting a structural form and design that can survive adequately the accidental removal of an individual element*
 - *tying the structure together.*
- 4) The above requirements shall be met by the choice of suitable materials, by appropriate design and detailing and by specifying control procedures for production, construction and use as relevant for the particular project.

2.2 Definitions and classifications

2.2.1 Limit states and design situations

2.2.1.1 *Limit states*

1) Limit states are states beyond which the structure no longer satisfies the design performance requirements.

Limit states are classified into:

- ultimate limit states
- serviceability limit states.

2) Ultimate limit states are those associated with collapse, or with other forms of structural failure which may endanger the safety of people.

3) States prior to structural collapse which, for simplicity, are considered in place of the collapse itself are also classified and treated as ultimate limit states, e.g. the bending resistance of a member having cross-sections in Class 3.

4) *Ultimate limit states which may require consideration include:*

- *loss of equilibrium of the structure or any part of it, considered as a rigid body*
- *failure by excessive deformation, rupture, or loss of stability of the structure or any part of it, including shear connection (i.e. the connection between the concrete and the steel parts), supports and foundations.*

Limit states may also concern only concrete or steel parts of the structure (e.g. the steel part during an erection phase), for which reference should be made to Eurocode 2 and Eurocode 3 respectively.

5) Serviceability limit states corresponds to states beyond which specified service criteria are no longer met.

6) *Serviceability limit states which may require consideration include:*

- *deformations or deflections which adversely affect the appearance or effective use of the structure (including the proper functioning of machines or services) or cause damage to finishes or non-structural elements*
- *vibration which causes discomfort to people, damage to the building or its contents, or which limits its functional effectiveness*
- *cracking of the concrete which is likely to affect appearance, durability or water-tightness adversely*
- *damage to concrete because of excessive compression, which is likely to lead to loss of durability*
- *slip at the steel-concrete interface when it becomes large enough to invalidate design checks for other serviceability limit states in which the effects of slip are neglected.*

2.2.1.2 *Design situations*

1) Design situations are classified as:

- persistent situations corresponding to normal conditions of use of the structure
- transient situations, for example during construction or repair
- accidental situations.

2) *For composite structures attention is drawn to the necessity of identifying and considering, when relevant, several transient design situations corresponding to the successive phases of the building process. For example, it may be necessary not only to consider the situation of the steel beam supporting the fresh concrete, but even to distinguish several situations corresponding to successive phases of pouring the concrete.*

2.2.2 Actions

[Note: fuller definitions of the classification of actions will be found in Eurocode 1.]

2.2.2.1 *Definitions and principal classification*

1) An action (F) is:

- a force (load) applied to the structure (direct action), or
- an imposed deformation (indirect action), e.g. temperature effects, settlement or shrinkage.

2) Actions are classified:

i) by their variation in time:

- permanent actions (G), e.g. self-weight of structures, fittings, ancillaries and fixed equipment
- variable actions (Q), e.g. imposed loads, wind loads or snow loads
- accidental actions (A), e.g. explosions or impact from vehicles

ii) by their spatial variation:

- fixed actions, e.g. self-weight [but see 2.3.2.3 2) for structures very sensitive to variations in self-weight]
- free actions, which result in different arrangements of actions, e.g. movable imposed loads, wind loads, snow loads.

3) *Supplementary classifications relating to the response of the structure are given in the relevant clauses.*

4) For composite structures, a classification of the effects of actions is adopted in calculations, as follows:

- shrinkage of concrete and non-uniform changes of temperature result in internal forces in cross sections, and curvatures and longitudinal strains in members. The effects that occur in isostatic structures, and also in hyperstatic structures when compatibility of the deformations is not considered, are classified as primary (isostatic) effects. For these effects, the associated actions have to be considered as direct or indirect [see 1) above], according to their nature
- the primary effects of shrinkage and temperature are associated in hyperstatic structures with additional action-effects, such that the total effects are compatible. These additional effects are classified as secondary (hyperstatic) effects. For these effects the associated actions, which are usually forces at external supports, are to be considered as imposed deformations (indirect actions).

This classification has consequences either in 2.3.3.1 4) hereafter if the global analysis is linear, or in the global analysis itself in the other cases.

2.2.2.2 Characteristic value of actions

1) Characteristic values F_k are specified:

- in Eurocode 1 or other relevant loading codes, or
- by the client, or the designer in consultation with the client, provided that the minimum provisions specified in the relevant loading codes or by the competent authority are observed.

2) For permanent actions where the coefficient of variation is large (e.g. for some earth pressures) or where the actions are likely to vary during the life of the structure (e.g. for some superimposed permanent loads), two characteristic values are distinguished, an upper ($G_{k, \text{sup}}$) and a lower ($G_{k, \text{inf}}$). Elsewhere a single characteristic value [G_k] is sufficient.

3) *The self-weight of the structure may, in most cases, be calculated on the basis of the nominal dimensions and mean unit masses.*

4) *Because of the continuous and monotonic variation in time of shrinkage, in most cases two values should be considered for this action, associated respectively with two extreme points of the design life, represented by the symbolic expressions $t = 0$ and $t = \infty$. In particular cases only the intermediate range should be investigated.*

5) For variable actions the characteristic value (Q_k) corresponds to either:

- the upper value with an intended probability of not being exceeded, or the lower value with an intended probability of not being reached, during some reference period, having regard to the intended life of the structure or the assumed duration of the design situation, or
- the specified value, e.g. an intended limit for use.

6) For accidental actions the characteristic value A_k (when relevant) generally corresponds to a specified value.

2.2.2.3 Representative values of variable actions

[Note: fuller definitions of representative values will be found in Eurocode 1.]

1) The main representative value is the characteristic value Q_k .

2) Other representative values are related to the characteristic value Q_k by means of a factor Ψ_i . These values are defined as:

- combination value: $\Psi_0 Q_k$ (see 2.3.2.2 and 2.3.4)
- frequent value: $\Psi_1 Q_k$ (see 2.3.2.2 and 2.3.4)
- quasi-permanent value: $\Psi_2 Q_k$ (see 2.3.2.2 and 2.3.4)

3) Supplementary representative values are used for fatigue verification and dynamic analysis.

4) The factors Ψ_0 , Ψ_1 and Ψ_2 are specified:

- in Eurocode 1 or other relevant loading codes, or
- by the client, or the designer in consultation with the client, provided that the minimum provisions specified in the relevant loading codes or by the competent authority are observed.

2.2.2.4 Design values of actions

1) The design value F_d of an action is expressed in general terms as:

$$F_d = \gamma_F F_k \quad (2.1)$$

where γ_F is the partial safety factor for the action considered — taking account of, for example, the possibility of unfavourable deviations of the actions, the possibility of inaccurate modelling of the actions, uncertainties in the assessment of effects of actions and uncertainties, in the assessment of the limit state considered.

2) Specific examples of the use of γ_F are:

$$G_d = \gamma_G G_k$$

$$Q_d = \gamma_Q Q_k \text{ or } \gamma_Q \Psi_i Q_k$$

$$A_d = \gamma_A A_k \text{ (if } A_d \text{ is not directly specified)}$$

3) The upper and lower design values of permanent actions are expressed as follows:

- where only a single characteristic value G_k is used [see 2.2.2.2 2)] then:

$$G_{d,\text{sup}} = \gamma_{G,\text{sup}} G_k$$

$$G_{d,\text{inf}} = \gamma_{G,\text{inf}} G_k$$

- where upper and lower characteristic values of permanent actions are used [see 2.2.2.2 2)] then:

$$G_{d,\text{sup}} = \gamma_{G,\text{sup}} G_{k,\text{sup}}$$

$$G_{d,\text{inf}} = \gamma_{G,\text{inf}} G_{k,\text{inf}}$$

where

- $G_{k,\text{inf}}$ is the lower characteristic value of the permanent action
- $G_{k,\text{sup}}$ is the upper characteristic value of the permanent action
- $\gamma_{G,\text{inf}}$ is the lower value of the partial safety factor for the permanent action
- $\gamma_{G,\text{sup}}$ is the upper value of the partial safety factor for the permanent action.

2.2.2.5 Design values of the effects of actions

1) The effects of actions (E) are response (for example, internal forces and moments, stresses, strains) of the structure to the actions. Design values of the effects of actions (E_d) are determined from the design values of the actions, geometrical data and material properties when relevant, in accordance with 2.3.1 4), as:

$$E_d = E(F_d, a_d, \dots) \quad (2.2)$$

where a_d is defined in 2.2.4.

2.2.3 Material properties

2.2.3.1 Characteristic values

1) A material property is represented by a characteristic value X_k which in general corresponds to a fractile in the assumed statistical distribution of the particular property of the material, specified by relevant standards and tested under specified conditions. Certain properties of some components (e.g., resistance of a shear connector P_{Rk}) are treated as material properties.

2) For some material properties a nominal value is used as the characteristic value; this is the case for most of the material properties relating to the steel parts of composite structures.

3) For other material properties the characteristic values are for some verifications substituted or supplemented by mean or nominal values, which correspond to the most likely values throughout the structure for which a minimum characteristic value has been specified; this is the case for concrete properties and for physical coefficients.

4) A material property may have two characteristic values, the upper value and the lower value. In most case only the lower values of strengths need to be considered. However the upper values shall be taken into account where overstrength effect may produce a significant reduction in safety; this is for example the case for the tensile strength of concrete in the calculation of the effects of indirect actions.

2.2.3.2 Design values

1) The design value X_d of a material property represented by its lower characteristic value is defined as:

$$X_d = X_{k,inf}/\gamma_M$$

where γ_M is the partial safety factor for the material property [see 2.3.3.2 1)].

However, the design value P_{Rd} of the resistance of a shear connector is defined in a similar way, as $P_{Rd} = P_{Rk}/\gamma_v$ where γ_v is a unified value applicable for any mode of failure of the shear connection.

2) For composite structures, the design values of the material strengths and geometrical data, when relevant, shall be used to determine the design resistances of members or cross-sections, according to the individual chapters, as:

$$R_d = R(X_d, a_d \dots) \quad (2.3)$$

in most cases. Where the resistance is influenced by the buckling of the structural steel, other formulations are used, including a specific safety factor γ_{Rd} [see 4.1.1 5)].

3) The design value R_d may be determined from tests. In this case R_d is defined according to formula (2.3) or as:

$$R_d = R(X_k, a_k \dots)/\gamma_M \quad (2.3bis)$$

where γ_M is a partial factor for the resistance [see 2.3.3.2 9)].

2.2.4 Geometrical data

1) Geometrical data are generally represented by their nominal values:

$$a_d = a_{nom} \quad (2.4)$$

2) In some cases the geometrical design values are defined by:

$$a_d = a_{nom} + \Delta a \quad (2.5)$$

where Δa is the additive partial safety margin for the geometrical datum.

The values of Δa are given in the appropriate clauses.

[ENV Note: Δa covers mainly imperfections but also, in some cases, deviations due to neglected parasitic phenomena, e.g. thermal differences.]

3) *Imperfections to be adopted in the global analysis of the structure are treated in 4.8.2.3 and 4.9.3.*

2.2.5 Load arrangements and load cases

[Note: detailed rules on load arrangements and load cases are given in Eurocode 1.

1) A load arrangement identifies the position, magnitude and direction of a free action.

2) A load case identifies compatible load arrangements, sets of deformations and imperfections considered for a particular verification.

3) For the relevant combinations of actions, sufficient load cases shall be considered to enable the critical design conditions to be established.

4) *Simplified load cases may be used, if based on a reasonable interpretation of the structural response.*

5) For continuous beams and slabs in buildings without cantilevers subjected to dominantly uniformly distributed loads, it will generally be sufficient to consider only the following load arrangements:

- alternate spans carrying the design variable and permanent loads ($\gamma_Q Q_k + \gamma_G G_k$), other spans carrying only the design permanent load $\gamma_G G_k$,
- any two adjacent spans carrying the design variable and permanent loads ($\gamma_Q Q_k + \gamma_G G_k$), all other spans carrying only the design permanent load $\gamma_G G_k$.

[ENV Note: 4) and 5) possibly to be transferred to Eurocode 1.]

2.3 Design requirements

2.3.1 General

- It shall be verified that no relevant limit state is exceeded.
- All relevant design situations and load cases shall be considered.
- Possible deviations from the assumed directions or positions of actions shall be considered.

[ENV Note: it is assumed that guidance will be found in relevant chapters of the Eurocode 1.]

4) Calculations shall be performed using appropriate design models (supplemented, if necessary, by tests) involving all relevant variables. The models shall be sufficiently precise to predict the structural behaviour, commensurate with the standard of workmanship likely to be achieved, and with the reliability of the information on which the design is based.

2.3.2 Ultimate limit states

2.3.2.1 Verification conditions

1) When considering a limit state of static equilibrium or of gross displacements or deformations of the structure, it shall be verified that:

$$E_{d,dst} \leq E_{d,stb} \quad (2.6)$$

where $E_{d,dst}$ and $E_{d,stb}$ are the design effects of destabilizing actions and stabilizing actions, respectively.

2) When considering a limit state of rupture or excessive deformation of a section, member or connection (fatigue excluded) it shall be verified that:

$$S_d \leq R_d \quad (2.7)$$

where S_d is the design value of an internal force or moment (or of a respective vector of several internal forces or moments) and R_d is the corresponding design resistance, as defined in 2.2.3.2 2) or 3).

3) When considering a limit state of transformation of the structure into a mechanism, it shall be verified that a mechanism does not occur unless actions exceed their design values, taking account of the respective design values of all structural properties.

4) When considering a limit state of stability induced by second-order effects, it shall be verified that instability does not occur unless actions exceed their design values, taking account of the respective design values of all structural properties. In addition, sections shall be verified according to 2) above.

[Note: Equation (2.8) of EC3 is not considered in this Part of EC4.]

2.3.2.2 Combinations of actions

1) For each load case, design values E_d for the effects of actions shall be determined from combination rules involving design values of actions as identified by Table 2.1

Table 2.1 — Design values of actions for use in the combination of actions

Design situation	Permanent actions G_d	Variable actions Q_d		Accidental actions A_d
		Leading variable action	Accompanying variable actions	
Persistent and Transient	$\gamma_G G_k$	$\gamma_Q Q_k$	$\Psi_0 \gamma_Q Q_k$	
Accidental (if not specified differently elsewhere)	$\gamma_{GA} G_k$	$\Psi_1 Q_k$	$\Psi_2 Q_k$	$\gamma_A A_k$ (if A_d is not specified directly)

- 2) The design values of Table 2.1 shall be combined using the following rules (given in symbolic form):
 — Persistent and transient design situations for verifications other than those relating to fatigue (fundamental combinations):

$$\sum_j \gamma_{G,j} G_{k,j} + \gamma_{Q,1} Q_{k,1} + \sum_{i>1} \gamma_{Q,i} \psi_{0,i} Q_{k,i} \quad (2.9)$$

- Accidental design situations (if not specified differently elsewhere):

$$\sum_j \gamma_{GA,j} G_{k,j} + A_d + \psi_{1,1} Q_{k,1} + \sum_{i>1} \psi_{2,i} Q_{k,i} \quad (2.10)$$

where:

- $G_{k,j}$ = characteristic values of the permanent actions
- $Q_{k,1}$ = characteristic value of one of the variable actions
- $Q_{k,i}$ = characteristic values of the other variable actions
- A_d = design value (specified value) of the accidental action
- $\gamma_{G,j}$ = partial safety factor for the permanent action $G_{k,j}$
- $\gamma_{GA,j}$ = as $\gamma_{G,j}$, but for accidental design situations
- $\gamma_{Q,i}$ = partial safety factor for the variable action $Q_{k,i}$
- and Ψ_0, Ψ_1, Ψ_2 are factors defined in 2.2.2.3.

- 3) Combinations for accidental design situations either involve an explicit accidental action A or refer to a situation after an accidental event ($A = 0$). Unless specified otherwise, $\gamma_{GA} = \boxed{1.0}$ may be used.

- 4) In expressions (2.9) and (2.10), indirect actions shall be introduced where relevant.

- 5) Simplified combinations for building structures are given in 2.3.3.1.

[Note: detailed rules on combinations of actions are given in Eurocode 1.]

2.3.2.3 Design values of permanent actions

- 1) In the various combinations defined above, those permanent actions that increase the effect of the variable actions (i.e. produce unfavourable effects) shall be represented by their upper design values and those that decrease the effect of the variable actions (i.e. produce favorable effects) by their lower design values [see 2.2.2.4 3)].

- 2) Where the results of a verification may be very sensitive to variations of the magnitude of the same permanent action from place to place in the structure, this action shall be treated as consisting of separate unfavourable and favourable parts. This applies in particular to the verification of static equilibrium.

- 3) Where a single permanent action is treated as consisting of separate unfavourable and favourable parts, allowance may be made for the relationship between these parts by adopting special design values [see 2.3.3.1 3) for building structures].

- 4) *Except for the cases mentioned in 2), the whole of each permanent action should be represented throughout the structure by either its lower or its upper design value, whichever gives the more unfavourable effect.*

- 5) *For continuous beams and frames, the same design value of the self-weight of the structure [evaluated as in 2.2.2.2 3)] may be applied to all spans, except for cases involving the static equilibrium of cantilevers (see clause 2.3.2.4 of EC3).*

2.3.2.4 Verification of static equilibrium

Clause 2.3.2.4 of EC3 is applicable.

2.3.3 Partial safety factors for ultimate limit states

2.3.3.1 Partial safety factors for actions on building structures

1) For the persistent and transient design situations the partial safety factors given in Table 2.2 shall be used.

Table 2.2 — Partial safety factors for actions on building structures for persistent and transient design situations

	Permanent actions (γ_G)	Variable actions (γ_Q)	
		Leading variable action	Accompanying variable actions
Favourable effect $\gamma_{F,inf}$	1.0 ^a	— ^b	— ^b
Unfavourable effect $\gamma_{F,sup}$	1.35 ^a	1.5	1.5

^a See also paragraph 3)
^b See Eurocode 1; in normal cases for building structures $\gamma_{Q,inf} = 0$

2) For accidental design situations to which equation (2.10) applies, the partial safety factors for the variable actions are taken as equal to 1.0. For permanent actions see 2.3.2.2 3).

3) Where, according to 2.3.2.3 2), a single permanent action needs to be considered as consisting of unfavourable and favourable parts, the favourable part may, as an alternative, be multiplied by

$$\gamma_{G,inf} = 1.1$$

and the unfavourable part by:

$$\gamma_{G,sup} = 1.35$$

provided that by applying $\gamma_{G,inf} = 1.0$ both to the favourable part and the unfavourable part does not give a more unfavourable effect.

4) For imposed deformations [see 2.2.2.1 1) and 4)], where non-linear methods of analysis are used, the factors for variable actions given above apply. For a linear calculation, the factor for unfavourable effects shall be reduced by 20 %.

5) For vectorial (i.e. multi-component) effects in columns, if a component of the effect is favourable, reference sum be made to 4.8.3.13 6).

6) For building structures, as a simplification, the expression (2.9) may be replaced by whichever the following combinations gives the larger value:

considering only the most unfavourable variable action:

$$\sum_j \gamma_{G,j} G_{k,j} + \gamma_{Q,1} Q_{k,1} \quad (2.11)$$

considering all unfavourable variable actions

$$\sum_j \gamma_{G,j} G_{k,j} + 0.9 \sum_{i \geq 1} \gamma_{Q,i} Q_{k,i} \quad (2.12)$$

2.3.3.2 Partial safety factors for resistances and material properties

1) Except in certain cases mentioned in 2.2.3.2 2) and 3) the factors γ_M are applied to lower characteristic or nominal strengths of materials [following 2.2.3.2 1)], and are as given in Table 2.3.

Table 2.3 — Partial safety factors for resistances & material properties

Combination	Structural steel γ_a (= γ_{M0} in EC3)	Concrete γ_c	Steel reinforcement γ_s	Profiled steel sheeting γ_{ap}
Fundamental	1.10	1.5	1.15	1.10
Accidental (except earthquakes)	1.0	1.3	1.0	1.0

2) The values in Table 2.3 are assumed to take account of, inter alia, differences between the strength of test specimens of the structural materials and their strength in situ. They are applicable to some elastic mechanical properties, but only in cases specified in the relevant clauses; in other cases they should be substituted by $\gamma_M = 1.0$. For physical non-mechanical coefficients (e.g. density, thermal expansion), γ_M shall be taken as equal to 1.0.

3) Higher or lower values of γ_c may be used if these are justified by adequate quality assurance procedures [see 1.3 2)].

4) Values of γ_M for shear connection are given as γ_v in 6.3.2.1 for studs, 6.3.7 for angle connectors and 6.5.2.1 for friction grip bolts. [ENV Note: γ_v is not yet defined for other types].

5) Values of γ_M for bolts, rivets, pins, welds, and slip resistance of bolted joints are as given in clause 6.1.1 2) of EC3.

6) Values of γ_M for longitudinal shear in composite slabs are given in 7.6.1.

7) For steel members in composite structures, values of γ_M for fundamental combinations are as given in the relevant clauses of Chapter 5 of Part 1.1 of Eurocode 3, or in Part 1.3 of Eurocode 3.

8) For reinforced concrete members in composite structures, values of γ_M are as given in clause 2.3.3.2 of EC2 [i.e. as given in 1) to 3) above].

9) Where structural properties are determined by testing, reference shall be made to Chapter 10 and Annex F.

2.3.4 Serviceability limit states

1) It shall be verified that:

$$E_d \leq C_d \text{ or } E_d \leq R_d \quad (2.13)$$

where:

C_d is a nominal value or a function of certain design properties of materials related to the design effect of actions considered, and

E_d is the design value of the effect of actions, determined on the basis of one of the combinations defined below.

The required combination is identified in the particular clause of chapter 5 for each serviceability verification.