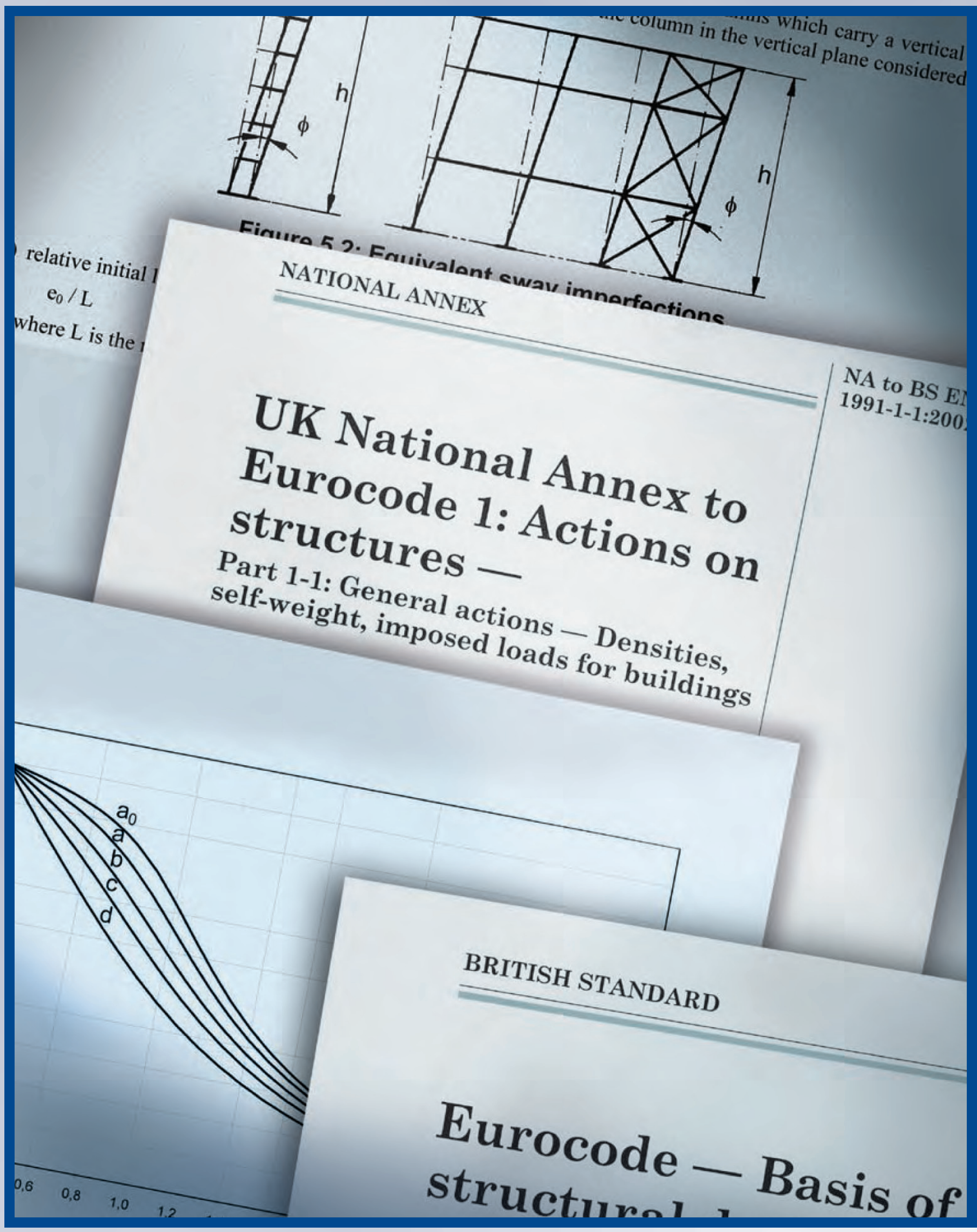
UK EUROCODES



SCI Steel Knowledge

TATA STEEL

BCSA

Steel Building Design:

Introduction to the Eurocodes

Steel Knowledge

SCI (The Steel Construction Institute) is the leading, independent provider of technical expertise and disseminator of best practice to the steel construction sector. We work in partnership with clients, members and industry peers to help build businesses and provide competitive advantage through the commercial application of our knowledge. We are committed to offering and promoting sustainable and environmentally responsible solutions

Our service spans the following five areas:

Membership
Individual and corporate membership

Technical information
Courses
Publications
Online reference tools

Education
Codes and standards

Construction solutions
Sustainability
Product development
Research
Engineering solutions

Communications technology
Websites

Communities
Design tools

Assessment
SCI assessed

The Steel Construction Institute, Silwood Park, Ascot, Berkshire, SL5 7QN.
Telephone: +44 (0) 1344 636525 Fax: +44 (0) 1344 636570
Email: membership@steel-sci.com

For information on publications, telephone direct: +44 (0) 1344 636513
or Email: publications@steel-sci.com

For information on courses, telephone direct: +44 (0) 1344 636500
or Email: education@steel-sci.com

World Wide Web site: www.steel-sci.org
24 X 7 technical information: www.steelbiz.org

SCI PUBLICATION P361

Steel Building Design: Introduction to the Eurocodes

M E Brettle BEng (Hons)

Published by:
The Steel Construction Institute
Silwood Park
Ascot
Berkshire SL5 7QN

Tel: 01344 636525
Fax: 01344 636570

Publication Number: SCI P361

ISBN 13: 978-1 85942-180-2

British Library Cataloguing-in-Publication Data.

A catalogue record for this book is available from the British Library.

FOREWORD

The design of steel framed buildings in the UK, including those where composite (steel and concrete) construction is used, has, since 1990, generally been in accordance with the British Standard BS 5950. However, that Standard is due to be withdrawn in March 2010; it will be replaced by the corresponding Parts of the Structural Eurocodes.

The Eurocodes are a set of structural design standards, developed by CEN (European Committee for Standardisation) over the last 30 years, to cover the design of all types of structures in steel, concrete, timber, masonry and aluminium. In the UK, they are published by BSI under the designations BS EN 1990 to BS EN 1999; each of these ten Eurocodes is published in several Parts and each Part is accompanied by a National Annex that implements the CEN document and adds certain UK-specific provisions.

SCI, BCSA and Tata Steel* have undertaken the preparation of a series of guidance publications to assist designers in the design of steel-framed buildings in accordance with the Eurocodes and this publication is the first in that series.

This publication offers a general overview of design to the Eurocodes but does not give detailed guidance.

The author of the publication is Miss M E Brettle, assisted by Mr D C Iles and Mr A L Smith, all of The Steel Construction Institute.

The preparation of this guide was funded by Tata Steel*, and their support is gratefully acknowledged.

* This publication includes references to Corus, which is a former name of Tata Steel in Europe

Contents

SUMMARY

This publication is the first in a series that will provide guidance on the use of the Structural Eurocodes for the design of steel-framed buildings. It explains that ten Structural Eurocodes have been developed; these cover all aspects of design for structures of steel, concrete, timber and masonry; these Standards are being adopted throughout Europe.

Section 1 of the publication introduces the Eurocode system, sets out the format that is used and explains the relationship between the Eurocodes, their National Annexes and non-contradictory complementary information (NCCI). Section 2 explains that the basis of structural design is set out in EN 1990 and that this defines the common principles and specifies how design values are to be determined and verified. Section 3 gives a brief summary of the various actions (loading) that are defined in EN 1991.

Section 4 introduces the various Parts of EN 1993 (Eurocode 3) that relate to the different design aspects of steelwork. The rules relating to design values of material properties, cross section resistances and member buckling resistances are described. Reference is also made to EN 1090, the Standard for the execution (fabrication and erection) of steelwork, which is an essential counterpart to the design rules.

Section 5 briefly introduces EN 1994 (Eurocode 4), for composite steel and concrete structures, and EN 1992 (Eurocode 2), which covers the design of the concrete elements in composite structures.

1 GENERAL

1.1 Scope

This publication has been prepared to help designers become familiar with the use of the Structural Eurocodes for the design of steel-framed buildings. It provides a general overview but does not contain specific design guidance - more detailed guidance is given in other publications produced by SCI, BCSA and Corus (see Section 6.1). The guidance is aimed at those who are familiar with limit state design, but who have little or no knowledge of the Structural Eurocodes.

A brief introduction to the Structural Eurocodes system is given, which includes an overview of the sections that make up a Eurocode, the terminology used and the conventions used for axes and symbols.

A short summary of the basis of structural design and the combinations of actions that should be considered is presented and the categories of actions for which the structure should be designed are listed.

An introduction is given to the aspects of detailed design that are covered by Part 1 of Eurocode 3 (steel structures) and Part 1 of Eurocode 4 (steel and concrete composite structures). It highlights where design guidance may be found in those Parts of the Eurocodes.

1.2 Format of the Structural Eurocodes

There are ten separate Structural Eurocodes:

EN 1990 Eurocode: Basis of structural design

EN 1991 Eurocode 1: Actions on structures

EN 1992 Eurocode 2: Design of concrete structures

EN 1993 Eurocode 3: Design of steel structures

EN 1994 Eurocode 4: Design of composite steel and concrete structures

EN 1995 Eurocode 5: Design of timber structures

EN 1996 Eurocode 6: Design of masonry structures

EN 1997 Eurocode 7: Geotechnical design

EN 1998 Eurocode 8: Design of structures for earthquake resistance

EN 1999 Eurocode 9: Design of Aluminium Structures

Each Eurocode is comprised of a number of 'Parts', which are published as separate documents. Each Part consists of:

- Main body of text
- Normative annexes
- Informative annexes

These form the full text of the Eurocode Part

The full text of each Eurocode Part is issued initially by CEN (European Committee for Standardisation) in three languages with the above 'EN' designations; national standards bodies may translate the text into other languages but may not make any technical changes. The information given in this text is thus the same for each country in Europe.

The Eurocode text is then provided with a front cover and foreword by each national standards body and published within that country using a designation with the national prefix - for example EN 1990 is published by BSI as BS EN 1990. The text may be followed by a National Annex (see Section 1.3 below) or a National Annex may be published separately.

The Eurocode Parts contain two distinct types of statement – 'Principles' and 'Application Rules'. The former must be followed, to achieve compliance; the latter are rules that will achieve compliance with the Principles but it is permissible to use alternative design rules, provided that they accord with the Principles (see EN 1990, 1.4(5)[1]). Within the text of the Eurocode, provision is made for national choice in the setting of some factors and in the choice of some design methods (i.e. the selection of particular Application Rules); the choices are generally referred to as Nationally Determined Parameters (NDP) and these are published in the National Annex to the Part.

The general principle that was adopted in drafting the Eurocodes was that there would be no duplication of Principles or Application Rules. Thus the design basis in EN 1990 applies irrespective of the construction material or the type of structure. For each construction material, requirements that are independent of structural form are given in 'General' Parts and form-specific requirements (such as for bridges) are given in other Parts (bridge rules are in Parts 2 of the respective material Eurocodes). The consequence of dividing the Eurocodes into these separate aspects is that, when designing a steel structure, many separate Eurocode documents will be required.

1.3 National Annexes

The National Annex (NA) is an essential document when using a Eurocode Part. Where the opportunity is given in the text of the Eurocode, the National Annex will:

- Specify the value of a factor
- Specify which design method to use
- State whether an informative annex may be used

Although the NA may specify the value of partial factors to be applied to actions and resistances, in many cases it simply accepts the value recommended in the Eurocode text.

In addition, the National Annex may give references to publications that contain non-contradictory complimentary information (NCCI) that will assist the designer. NCCI is discussed in Section 1.5.

[1] A Note to that clause states: "If an alternative design rule is substituted for an application rule, the resulting design cannot be claimed to be wholly in accordance with EN 1990 although the design will remain in accordance with the Principles of EN 1990."

The guidance given in a National Annex applies to structures that are to be constructed within that country. National Annexes are likely to differ between countries within Europe.

The National Annexes for the country where the structure is to be constructed should always be consulted in the design of a structure.

1.4 Additional information

In most Eurocode Parts, Principles are denoted by the use of the letter 'P' after the clause number e.g. 1.2(3)P; whereas Application rules do not contain the letter 'P' e.g. 1.2(3).

Supplementary provisions for the design of buildings are indicated in some general Parts by the addition of the letter 'B' after the clause number e.g. 1.2(3)B.

Eurocode terminology

Some of the terminology used in the Eurocodes will be new to UK designers, but terms have been chosen carefully, for clarity and to facilitate unambiguous translation into other languages. The presentation of symbols has also been rigorously defined (although not always consistently applied) and some conventions are different.

The chief differences in terminology are:

'Actions'	=	loads, imposed displacements, thermal strains
'Effects'	=	internal bending moments, axial forces etc.
'Resistance'	=	capacity of a structural element to resist bending moment, axial force, shear, etc.
'Verification'	=	check
'Execution'	=	construction (fabrication, erection, etc.)

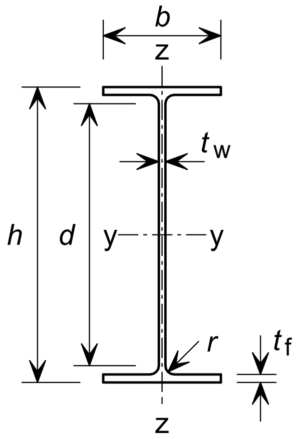
Eurocode symbols

The Eurocode system uses the ISO convention for symbols and sub-scripts. Where multiple sub-scripts occur, a comma is used to separate them. Four main sub-scripts and their definitions are given below:

Eurocode Subscript	**Definition**	**Example**	
Ed	Design value of an effect	M_{Ed}	Design bending moment
Rd	Design resistance	M_{Rd}	Design resistance for bending
el	Elastic property	W_{el}	Elastic section modulus
pl	Plastic property	W_{pl}	Plastic section modulus

Geometrical axes

The convention for member axes and symbols for section dimensions used in the Eurocodes are shown below.



Major axis	y-*y*
Minor axis	z-*z*
Longitudinal axis of element	x-*x*

Figure 1.1 *Axis convention and symbols for principal dimensions*

1.5 Non-contradictory complementary information (NCCI)

Non-contradictory complimentary information (NCCI) is guidance that will assist the designer when designing a structure to the Eurocodes. According to CEN rules, a National Annex cannot contain NCCI, but references to NCCI may be given. As the name suggests, any guidance that is referenced in the National Annex must not contradict the principles of the Eurocode.

The Eurocodes omit some design guidance where it is considered to be readily available in text books or other established sources. Publications that contain such design guidance may be referenced in the National Annex as NCCI.

Additionally, BSI is publishing NCCI guidance in the form of 'Published Documents' (PDs). These documents are only informative and do not have the status of a Standard. PDs that may be of help to building designers are given in Section 6.

1.6 Building Regulations

Approved Document A to the Building Regulations (England and Wales) does not currently reference the Eurocodes; it will do so when it is next updated in 2013. In the meantime, it is expected that DCLG (Department of Communities and Local Government) will confirm the suitability of the Eurocodes to meet the requirements of the Regulations in early 2010.

Regulations in Scotland and Northern Ireland will also be updated to refer to the Eurocodes.

2 BASIS OF STRUCTURAL DESIGN

EN 1990 can be considered as the 'core' document of the structural Eurocode system as it establishes the principles and requirements for the safety, serviceability and durability of structures. It also describes the basis for structural design and verification. The main sections of EN 1990 include:

- Requirements
- Principles of limit state design
- Basic variables
- Structural analysis and design assisted by testing
- Verification by the partial safety factor method.

2.1 Basic requirements

The basic requirements are the obvious ones that the structure shall be designed to have adequate structural resistance to sustain the actions and influences on it, that it should remain serviceable and be durable. It should also have adequate fire resistance and be 'robust' - i.e. not disproportionately damaged by accidental events. The UK National Annex gives indicative values for the design working life of a structure or building within the UK.

2.2 Limit state design

The principles of limit state design are set out briefly and the relevant design situations are classified as:

Persistent	–	Conditions of normal use.
Transient	–	Temporary conditions e.g. during repair.
Accidental	–	Exceptional conditions applicable to the structure or to its exposure, e.g. to fire, explosion or impact.
Seismic	–	Conditions applicable to the structure when subjected to seismic events.

Ultimate and serviceability limit states are defined and the requirement that verifications (checks) shall be carried out is stated.

2.3 Basic variables

Actions

Actions are classified as:

Permanent actions	–	e.g.	Self-weight of structural members, fixed equipment and indirect actions such as shrinkage
Variable actions	–	e.g.	Imposed floor loads, wind loads.
Accidental actions	–	e.g.	Explosions, vehicle impact.

The definition of characteristic value[2] of an action is given for each class of action, in relation to its probability of occurrence.

Material and product properties

EN 1990 also states that material and product properties are represented by characteristic values. Characteristic values are defined in the relevant material Eurocode Parts, either based on statistical values from test results or, more commonly, in relation to values specified in a product standard.

Geometric data

Geometric data (dimensions) are also represented by their characteristic values; EN 1990 states that the characteristic values may be taken as the dimensions specified in the design.

2.4 Analysis

The requirement is essentially that appropriate structural models be used to determine the effects of the actions (i.e. to determine the deformations, displacements, member forces). No specific guidance is given in EN 1990; requirements related to global analysis are given in the material Parts of the Eurocodes.

For structures exposed to fire, appropriate models of both temperature evolution and the variation of material properties at elevated temperature are required.

2.5 Verification by partial factor method

Principles are set out for the use of the partial factor method for verification at the various limit states.

Design values

Design values of actions, material properties and resistances are defined in relation to specific partial factors applied to characteristic values (recommended values of partial factors are given for buildings in Annex A1 of EN 1990).

Although in principle there are three classes of partial factor, applied to actions, to effects of actions (to represent uncertainty in modelling) and to material properties, the second of these is normally incorporated into the value of the factor applied to actions. Thus, EN 1990 generally refers to only two classes:

γ_F applied as a multiplier to the characteristic value of an action

γ_M applied as a divisor to the characteristic value of a material property (member resistance).

[2] The term 'characteristic value' applies to actions, material properties and geometrical properties and is defined for each in EN 1990. Generally, it means a representative value that has a certain (low) probability of being exceeded (where a greater value would be more onerous) or of not being exceeded (where a lesser value would be more onerous).

Ultimate limit states

The following ultimate limit states are required to be verified:

EQU	Loss of static equilibrium of the structure or a structural element
STR	Failure or excessive deformation of a structure or structural element
GEO	Failure or excessive deformation of the ground where the strengths of soil or rock are significant in providing resistance
FAT	Fatigue failure of the structure or structural elements.

Note: The EQU limit state does not normally need to be considered for building structures (other than overall overturning and sliding). The combination of actions for the FAT limit state are given in the material Eurocodes (EN 1992 to EN 1999)

For the STR and GEO limit states, the basic requirement is expressed generally as:

$E_d \leq R_d$

where:

E_d is the design value of the effect of actions such as internal force, moment or a vector representing several internal forces or moments;

R_d is the design value of the corresponding resistance.

The effects of actions depends on the combinations of actions that can occur and EN 1990 gives expressions for the effects for three classes of combination of actions at the ultimate limit state:

- Fundamental combinations (for persistent and transient situations)
- Combinations for accidental situations
- Combinations for seismic situations.

For fundamental combinations, EN 1990 gives the two alternative methods to determine the design value of the effects of combined actions. The design value may be determined from either expression 6.10 or from the less favourable of expressions 6.10a and 6.10b.

The first method is to express the combination of actions as:

$$\sum_{j\geq 1} \gamma_{G,j} G_{k,j} \text{ "+" } \gamma_P P \text{ "+" } \gamma_{Q,1} Q_{k,1} \text{ "+" } \sum_{i>1} \gamma_{Q,i} \psi_{0,i} Q_{k,i} \qquad (6.10)$$

The second method is to give two expressions for the combination of actions; the combination that gives the most onerous value should be used for the design verifications:

$$\sum_{j\geq 1} \gamma_{G,j} G_{k,j} \text{ "+" } \gamma_P P \text{ "+" } \gamma_{Q,1} \psi_{0,1} Q_{k,1} \text{ "+" } \sum_{i>1} \gamma_{Q,i} \psi_{0,i} Q_{k,i} \qquad (6.10a)$$

$$\sum_{j\geq 1} \xi_j \gamma_{G,j} G_{k,j} \text{ "+" } \gamma_P P \text{ "+" } \gamma_{Q,1} Q_{k,1} \text{ "+" } \sum_{i>1} \gamma_{Q,i} \psi_{0,i} Q_{k,i} \qquad (6.10b)$$

where:

'+' implies 'to be combined with'

Σ implies 'the combined effect of'

$G_{k,j}$ represents the characteristic value of the j-th unfavourable permanent action

P is a prestressing action

$Q_{k,1}$ is the characteristic value of the leading variable action ('main accompanying action' in 6.10a)

$Q_{k,i}$ represents the characteristic value of the i-th accompanying variable actions ($i > 1$)

γ_G γ_P γ_Q are representations of the factor γ_F according to the type of action to which they relate

ψ is a factor applied to an accompanying action

ξ is a reduction factor applied to unfavourable permanent actions (in 6.10b).

The National Annex for the country in which the building is to be constructed must be consulted for guidance on which method to use. In the UK, the National Annex allows either approach to be used. However, in almost all persistent design situations the use of the second method (the use of expressions 6.10a and 6.10b) will produce the lower design values of the effects of actions (and for buildings, 6.10b usually gives the governing value). For the transient design situation during execution, 6.10a is effectively the same as 6.10 (since $\psi = 1.0$ – see BS EN 1991-1-6 clauses A.1.1 and NA 2.18) and thus governs rather than 6.10.

For the majority of steel elements, the above expressions will simplify, as prestressing actions (P) will not be present.

When determining the most onerous combination of actions for a design situation where more than one independent variable action occurs, each variable action in turn should be considered as either the *'leading'*, or *'main accompanying'* variable action.

For building design, Annex A of EN 1990 gives recommended values of the factors γ , ψ and ξ; for buildings in the UK, the values are given in the National Annex to BS EN 1990, clause NA.2.2. Table A.1 in Appendix A of this document summarises the partial, combination and reduction factors that should be applied in the UK when multiple independent variable actions occur.

Similar expressions for combinations of actions in accidental and seismic situations are given in EN 1990. An example of an accidental design situation is fire limit state design. Design guidance for fire limit state design is given in SCI publication P375.

Serviceability Limit State

The serviceability limit state combinations of actions used are:

Characteristic combination	Irreversible limit state which includes the functioning of the structure, damage to finishes or non-structural elements.
Frequent combination	Reversible limit state
Quasi-permanent combination	Reversible limit states and long term effects

The expressions for the combinations of actions given in EN 1990 for serviceability limit state design are shown below.

Characteristic combination:

$$\sum_{j\geq 1} G_{k,j} + P + Q_{k,1} + \sum_{i>1} \psi_{0,i} Q_{k,i} \qquad (6.14b)$$

Frequent combination:

$$\sum_{j\geq 1} G_{k,j} + P + \psi_{1,1} Q_{k,1} + \sum_{i>1} \psi_{2,i} Q_{k,i} \qquad (6.15b)$$

Quasi-permanent combination

$$\sum_{j\geq 1} G_{k,j} + P + \sum_{i\geq 1} \psi_{2,i} Q_{k,i} \qquad (6.16b)$$

Recommended values of the combination coefficients (ψ) for buildings are given in Annex A of EN 1990; for building design in the UK, the values are given in the National Annex to BS EN 1990, clause NA.2.2.

The serviceability limits for vertical and horizontal deflections and dynamic effects may be given in the relevant material Eurocode.

The National Annex to BS EN 1990, clause A.1.4.2, says that the above combinations of actions should be used in the absence of specific requirements in the material Parts of the Eurocodes. In the UK, the National Annex to BS EN 1993-1-1 gives suggested limits for vertical and horizontal deflections for buildings due to variable actions only (i.e. no inclusion of deflections due to permanent actions); these limits are applicable only to certain members.

With agreement from the Client, different limits may be used for a specific project.

3 ACTIONS

Characteristic values of actions are given in the various Parts of EN 1991 *Eurocode 1: Actions on structures*. The design of building structures is likely to need to make reference to most, if not all, of the seven 'General' Parts:

EN 1991-1-1	General actions. Densities, self-weight, imposed loads for buildings
EN 1991-1-2	General actions. Actions on structures exposed to fire
EN 1991-1-3	General actions. Snow loads
EN 1991-1-4	General actions. Wind actions
EN 1991-1-5	General actions. Thermal actions
EN 1991-1-6	General actions. Actions during execution
EN 1991-1-7	General actions. Accidental actions

3.1 Self weight and imposed loads

EN 1991-1-1 gives design guidance and values of actions to be used when designing buildings and civil engineering works. Information is given for the following:

- Densities of construction and stored materials
- Self-weight of construction works
- Imposed loads for buildings.

Densities of construction and stored materials

Annex A of EN 1991-1-1 presents nominal values for the densities for construction and stored materials. Where relevant, the angle of repose is given for stored materials. The nominal values given in Annex A may be considered as characteristic for design purposes.

It should be noted that Annex A is 'Informative' and the relevant National Annex should be consulted to determine whether the values should be used. The UK National Annex states that the values in Annex A may be used.

Self-weight of construction works

Section 5 of EN 1991-1-1 gives guidance on determining the self-weight of construction works. A single characteristic value should be determined based on the nominal dimensions and the characteristic density values.

The self-weight of the construction works should include:

- Structural elements
- Non-structural elements such as fixed services and the weight of earth and ballast.

To account for the self weight of moveable partitions in buildings, an equivalent uniformly distributed load should be added to the imposed floor loads.

Imposed loads

Section 6 of EN 1991-1-1 gives recommended characteristic values for imposed loads for buildings. The values are given for the following categories of use:

Category A	Areas for domestic and residential activities
Category B	Office areas
Category C	Areas where people may congregate
Category D	Shopping areas
Category E	Areas for storage and industrial activities
Category F	Traffic and parking areas within buildings for vehicles ($\leq$ 30 kN and $\leq$ 8 passenger seats)
Category G	Traffic and parking areas within buildings for vehicles ($>$ 30 kN and $\leq$ 160 kN, on two axles)
Category H	Roofs not accessible except for maintenance and repair
Category I	Roofs accessible with occupancy according to categories A to D
Category K	Roofs accessible for special services, e.g. helicopter landing areas

Categories A, C, D, E and I are divided into sub-categories within the text of the Eurocode. The National Annex may also provide additional sub-categories to categories A to D.

Recommended horizontal loads on parapets and partition walls acting as barriers for categories A to G are given in EN 1991-1-1.

The imposed floor load from a single category may be reduced according to the areas supported by the member. A recommended expression for determining the reduction factor α_A is given.

For columns and walls supporting several storeys of areas in categories A to D, the total imposed load may be reduced by applying a reduction factor α_n. A recommended expression for determining α_n is given. Where imposed loads on floors act simultaneously with other variable actions (e.g. wind and snow) the total imposed load for that combination should be considered as a single action.

For both the above reduction factors (α_A and α_n), values for buildings in the UK are given by the National Annex to BS EN 1991-1-1, clauses NA.2.5 and NA.2.6.

3.2 Actions due to fire

The methods given in EN 1991-1-2 should be used to determine the thermal and mechanical actions that act on structures exposed to fire. The values of actions determined should be used when carrying out fire engineering design to Part 1-2 of the relevant material Eurocode. The values of actions determined are considered to be accidental actions.

3.3 Snow loads

EN 1991-1-3 gives guidance for determining the characteristic imposed roof loads due to snow. The characteristic values are determined using the characteristic ground snow load for the site and a roof shape coefficient. Ground snow load maps for European climatic regions are given in Informative Annex C of the Eurocode. The National Annex should be consulted to determine whether the map in Annex C should be used. The UK National Annex includes a different ground snow load map; this should be used for buildings constructed in the UK.

Annex B of EN 1991-1-3 presents shape coefficients for exceptional snow drifts for: multi-span pitched roofs; roofs abutting and close to taller structures; and roofs with projections, obstructions and parapets. These drifts are considered to be ‘exceptional’ drifts as they occur infrequently. Exceptional snow drifts should be treated as accidental actions. The use of Annex B is allowed through the National Annexes; the UK National Annex specifies the use of Annex B.

3.4 Wind actions

The information given in EN 1991-1-4 should be used to determine the natural wind actions to be considered during the structural design of buildings and civil engineering works. The information given is applicable to the whole or part of a structure, including elements attached to it such as cladding.

The values of wind actions are derived from a fundamental value of the basic wind velocity (which is given in the appropriate National Annex), from which a mean wind speed and peak velocity pressure are determined for the particular building; wind pressures and forces are determined using coefficients given in EN 1991-1-4. The UK National Annex provides numerous Tables and Figures for determining values for buildings in the UK.

3.5 Thermal actions

Where structures are exposed to daily and seasonal climatic changes in temperature, the effects of thermal actions should be accounted for in the design. EN 1991-1-5 gives principles and general rules that should be used to determine the characteristic values of thermal actions.

The guidance given in EN 1991-1-5 may also be used when determining the reference temperature to use when determining the steel sub-grade using EN 1993-1-10 (see Section 4.4).

3.6 Actions during execution

The values of actions which should be taken into account during the construction of a building or civil engineering works should be obtained from the principles and general rules given in EN 1991-1-6.

EN 1991-1-6 may also be used to determine the execution actions present on temporary works such as cofferdams, falsework, scaffolding and propping systems. However, EN 1991-1-6 does not provide rules for the actions that should be considered for complete temporary structures such as a bridge for temporarily diverted traffic.

3.7 Accidental actions

Strategies and rules for safeguarding buildings and other civil engineering works against accidental actions are given in EN 1991-1-7. There are no rules for determining specific values of accidental actions caused by external explosions, warfare or terrorist activities, or for verifying the residual stability of structures damaged by seismic action or fire, etc.

Information regarding limiting the effects of a localised failure in buildings from an unspecified cause is given in Annex A of EN 1991-1-7. Annex A includes information relating to:

- Categorisation of consequence classes for buildings
- Provision of horizontal and vertical ties
- Design of 'key elements'.

The National Annex to BS EN 1991-1-7 makes few changes in relation to recommended values and design methods for buildings, apart from modifying values of impact forces from vehicles.

4 DESIGN OF STEEL STRUCTURES

EN 1993-1 Eurocode 3: *Design of steel structures* comprises a set of general rules in twelve parts (EN 1993-1-1 to EN 1993-1-12) for all types of steel structure and additional rules in separate Parts for structures other than buildings (e.g. EN 1993-2 for bridges). When designing a building structure of rolled sections and plate girders, the following parts of EN 1993-1 will be required.

EN 1993-1-1	General rules and rules for buildings
EN 1993-1-2	Structural fire design
EN 1993-1-5	Plated structural elements
EN 1993-1-8	Design of joints
EN 1993-1-10	Material toughness and through-thickness properties

For steel and concrete composite structures, Eurocode 3 is referred to by Eurocode 4 for the design of steel elements (Eurocode 4 is discussed in Section 5.

4.1 EN 1993-1-1: General rules and rules for buildings

EN 1993-1-1 gives generic design rules for steel structures and specific guidance for structural steelwork used in buildings. Comments on the main aspects in EN 1993-1-1 are given below.

4.1.1 Material properties

The rules in EN 1993-1-1 relate to structural steel grades S235 to S460 in accordance with EN 10025, EN 10210 or EN 10219 (published by BSI as BS EN 10025, etc.) and thus cover all the structural steels likely to be used in buildings. In exceptional circumstances, components might use higher strength grades; EN 1993-1-12 gives guidance on the use of EN 1993-1-1 design rules for higher strength steels. For the design of stainless steel components and structures, reference should be made to EN 1993-1-4.

The nominal yield strength (f_y) and ultimate strength (f_u) of the steel material may be obtained using either Table 3.1 of EN 1993-1-1 or the minimum specified values according to the product standards. The National Annex may choose which method to use. The UK National Annex chooses the use of the values in the product standards, which means that there are more 'steps' in the reduction of yield and ultimate strengths with increasing thickness of the element. It should be noted that the specific product standard for the steel grade (e.g. EN 10025-2) is required when determining strength values, since there is a slight variation between the Parts of EN 10025 for the strength of thicker elements.

Structural steels are required to have adequate fracture toughness and, in some cases, improved through-thickness properties. Reference is made to EN 1993-1-10 - see further comment in Section 4.4.

Material requirements for fasteners (bolts) are referred to in EN 1993-1-8 - see Section 4.3.

4.1.2 Structural analysis and stability

Section 5.2 of EN 1993-1-1 gives guidance on global analysis of structures and the structural stability of frames. It considers the effects of two types of imperfections:

- Global imperfections for frames and bracing systems. These may be modelled explicitly in the overall structural analysis or may be modelled using equivalent horizontal forces (EHF) to represent initial sway imperfections. (The values of EHF thus depend on the values of internal forces for the particular combination being considered.)
- Local imperfections for individual members. Although these can be treated within an overall analysis, if the model is sufficiently detailed, they are normally accounted for implicitly within the procedures for determining the resistances of individual members (i.e. resistance to buckling).

Generally, first order elastic global analysis may be used. In some circumstances (depending on member classification) plastic global analysis may be used. Where the internal moments and forces are significantly increased due to deflections, second order effects need to be taken into account, either through magnification of first order effects or by a second order analysis.

4.1.3 Section classification

Four classes of cross section are defined in EN 1993. Each part of a section that is in compression is classified and the class of the whole cross section is deemed to be the highest (least favourable) class of its compression parts. Table 5.2 of EN 1993-1-1 gives limits for the width to thickness ratios for the compression parts of a section for each classification.

4.1.4 Cross sectional resistance

Expressions for determining the cross sectional resistance in tension, compression, bending and shear for the four classes of sections are given in Section 6.2 of EN 1993-1-1. The design values of resistance are expressed as $N_{t,Rd}$, $N_{c,Rd}$, $V_{c,Rd}$ and $M_{c,Rd}$ respectively.

For slender webs, the shear resistance may be limited by shear buckling; for such situations, reference is made to EN 1993-1-5 (see Section 4.2). Shear buckling is rarely a consideration with hot rolled sections.

4.1.5 Buckling resistance of members

Members in compression

EN 1993-1-1 presents guidance for checking flexural, torsional and torsional-flexural buckling for members in compression. It requires flexural buckling resistance to be verified for all members; torsional and torsional-flexural buckling resistances only need to be verified for members with open cross sections.

A set of five buckling curves is given in Figure 6.4 of EN 1993-1-1. The buckling curve is selected appropriate to the cross section type and the axis about which the column buckles. The curves give the value of a reduction factor χ dependent on the non-dimensional slenderness of the member $\bar{\lambda}$. The factor χ is applied as a multiplier to the resistance of the cross section.

The value of $\bar{\lambda}$ for flexural buckling is given by a simple rule in the Eurocode.

The guidance given in the Eurocode for calculating the slenderness for torsional and torsional-flexural buckling does not include the determination of the relevant elastic critical buckling force, which is required to determine the non-dimensional slenderness. NCCI is available in document SN001a-EN-EU on the Access Steel web site (see Section 6.6) for the determination of the critical axial compressive forces for failure due to torsional and torsional-flexural buckling.

Generally, for columns using hot rolled I and H sections, torsional or torsional-flexural buckling will not determine the buckling resistance of the column.

Members in bending

Laterally unrestrained members in bending about their major axes need to be verified against lateral torsional buckling.

Four buckling curves are defined for lateral torsional buckling, in a similar way to those for buckling of members in compression, but the curves are not illustrated in EN 1993-1-1. As for buckling in compression, a reduction factor χ_{LT} is determined, dependent on the non-dimensional slenderness $\bar{\lambda}_{LT}$ and on the cross section; the rules are given in clause 6.3.2 of EN 1993-1-1.

For uniform members in bending, three approaches are given:

- Lateral torsional buckling curves – general case
- Lateral torsional buckling curves for rolled sections and equivalent welded sections
- A simplified assessment method for beams with discrete lateral restraints to the compression flange in buildings.

The guidance given for calculating the beam slenderness for the first two approaches requires the value of the elastic critical moment for lateral torsional buckling (M_{cr}), but no expressions are given for determining this value. An NCCI method for calculating beam slenderness for rolled I, H and channel sections is given in SCI publication P362. NCCI for calculating M_{cr} is provided on the Access Steel web site.

The third method treats the compression flange and part of the web as a compression member.

Members in bending and axial compression

For members subject to bending and axial compression, the criteria given in 6.3.3 of EN 1993-1-1 must be satisfied.

Interaction factors (k_{ij}) used in the verifications may be calculated using either method 1 or 2 given respectively in Annexes A or B of EN 1993-1-1. Method 2 is considered to be the simpler of the two methods.

General method for lateral and lateral torsional buckling

The general method given in 6.3.4 of EN 1993-1-1 should not be confused with the general case for lateral torsional buckling given in 6.3.2.2 of EN 1993-1-1.

The general method gives guidance for structural components that are not covered by the guidance given for compression, bending or bending and axial compression members, and is not likely to be used by most building designers.

Lateral torsional buckling with plastic hinges

Section 6.3.5 of EN 1993-1-1 presents guidance for buildings that are designed using plastic analysis, such as portal frames.

4.1.6 Serviceability limit states

EN 1993-1-1 does not give any serviceability limit state limits for dynamic effects, vertical deflections and horizontal deflections. The National Annex for the country where the building is to be constructed should be consulted for guidance. The UK National Annex gives suggested limits for deflections; limits for specific projects should be agreed with the client if they differ from the suggestions.

4.1.7 Additional guidance for buildings

Informative Annex BB of EN 1993-1-1 gives guidance for buckling of structural components in buildings. Guidance is given for:

- Flexural buckling of members in triangulated and lattice structures
- Continuous restraints
- Stable lengths of segments containing plastic hinges for out-of-plane buckling.

4.2 EN 1993-1-5: Plated structural elements

The provisions of EN 1993-1-5 are mainly appropriate to the design of plate girders, where the elements of the cross section are typically more slender. For building frames using hot rolled sections, there is little need to refer to this Part, except for the design of webs subject to transverse forces due to concentrated local forces (commonly referred to as the determination of web bearing and buckling resistances).

Webs subject to transverse forces

Section 6 of EN 1993-1-5 gives a method for determining the resistance of webs to transverse forces. This method should only be used for rolled I and H sections and welded girders. Although not stated, the method should not be used for structural hollow sections as it gives a single check that combines the web bearing and buckling effects. For structural hollow sections, the NCCI method given in SCI publications P363 and P374 should be used.

4.3 EN 1993-1-8: Design of joints

EN 1993-1-8 gives rules for the design of joints between structural members. Both bolted and welded connections are covered. (Note that a joint is defined as a zone where two or more members are interconnected and a connection is the location where elements meet and is thus the means to transfer forces and moments.)

EN 1993-1-8 gives guidance for the design of joints subject to predominantly static loading. The steel grades covered are S235, S275, S355 and S460.

EN 1993-1-8 classifies joints according to their rotational stiffness as nominally pinned, rigid or semi-rigid and according to their strength as nominally pinned, full-strength or partial-strength. The appropriate type of joint model to be used in global analysis depends on this classification and the method of global analysis.

4.3.1 Bolted connections

EN 1993-1-8 defines five categories of bolted connections. These categories distinguish between connections loaded in shear or tension, and connections containing preloaded or non-preloaded bolts. A distinction is also made between preloaded bolts that have slip resistance at the serviceability limit state and slip resistance at the ultimate limit state. Minimum edge and end distances and bolt spacings are given in terms of the diameter of the bolt hole.

For a group of bolts subject to shear, the design resistance depends on the shear and bearing resistance calculated for each bolt within the group. If the design shear resistance of each bolt is greater than or equal to the bearing resistance the design resistance for the group of bolts may be taken as the sum of the bearing resistances of the individual bolts. Otherwise the design resistance of a group of bolts should be taken as the smallest shear or bearing resistance for any individual bolt multiplied by the number of bolts in the group.

Bolts

Nominal yield (f_{yb}) and ultimate tensile (f_{ub}) strengths are given for a wide range of bolt classes in Table 3.1 EN 1993-1-8; the UK National Annex restricts design to the use of classes 4.6, 5.6, 8.8 and 10.9. The nominal values given should be adopted as characteristic values.

4.3.2 Welded connections

EN 1993-1-8 gives guidance for the design of the following types of welds:

- Fillet welds
- Fillet welds all round
- Full penetration butt welds
- Partial penetration butt welds
- Plug welds
- Flare groove welds.

Design resistances of fillet and partial penetration welds are expressed in relation to their throat thickness (rather than leg length) and the ultimate strength of the material joined.

4.4 EN 1993-1-10: Material toughness and through-thickness properties

Fracture toughness

Maximum permissible element thicknesses, reference stresses and toughness qualities for different reference temperatures and steel grades are given in Table 2.1 of EN 1993-1-10.

The UK National Annex gives values of temperature adjustments to take account of reference stress, detail type etc. (These adjustments are applied to the lowest steel temperature, determined from EN 1991-1-5, to give the reference temperature.) PD 6695-1-10 gives NCCI tables that will enable the determination of maximum permissible thicknesses without considering the individual adjustments and without reference to Table 2.1 in EN 1993-1-10. It simplifies the use of EN 1993-1-10 for buildings in the UK.

Fracture toughness guidance given in EN 1461 should be used for hot dip galvanized elements.

Through-thickness properties

During the manufacture of steel plates and sections, imperfections within the thickness of the steel can occur. Very small imperfections within a steel plate may lead to the occurrence of 'lamellar tearing' when the plate is subject to through-thickness stress as tears may propagate from one imperfection to another. High through-thickness stresses may occur at weld locations, which may lead to 'lamellar tearing' occurring either during or shortly after the cooling of the weld.

Joints where 'lamellar tearing' might occur are:

- Cruciform joints
- Tee joints
- Corner joints.

Guidance on the prevention of lamellar tearing may be found in PD 6695-1-10

4.5 Execution class of structure

The design rules in EN 1993 apply to steelwork that has been executed (fabricated and constructed) in accordance with EN 1090.

EN 1090-2 specifies general requirements for the execution of structural steelwork as structures or manufactured components, depending on the Execution Class of the structure. Four Execution Classes are identified (EXC1, EXC2, EXC3 and EXC4), and more onerous fabrication and erection requirements are demanded for the higher numbered Execution Classes.

The provisions in EN 1090-2 cover the following types of steel:

- Hot rolled structural steel products in steel grades up to and including S690
- Cold formed components and sheeting in steel grades up to and including S690 for carbon steels and S700 for stainless steels
- Hot finished and cold formed austenitic, austenitic-ferritic and ferritic stainless steel products
- Hot finished and cold formed structural hollow sections, including standard range and bespoke rolled products and hollow sections manufactured by welding.

Although the requirements of EN 1090-2 mainly affect steelwork contractors, designers need to be aware of the provisions in the Standard. The designer should normally explicitly specify the execution class for any steel structure or structural element but if no class is specified the requirements for EXC2 will apply.

The requirements of EN 1090-2 apply to both permanent and temporary steel structures.

5 DESIGN OF COMPOSITE STRUCTURES

When designing a steel and concrete composite building, the following parts of EN 1994 *Eurocode 4: Design of composite steel and concrete structures* will be required:

EN 1994-1-1 General rules and rules for buildings

EN 1994-1-2 Structural fire design

Within these Parts, reference is made to EN 1993 (Eurocode 3) and to EN 1992 *Eurocode 2: Design of concrete structures*, notably to:

EN 1992-1-1 General rules and rules for buildings

EN 1992-1-2 Structural fire design

5.1 EN 1994, Eurocode 4

5.1.1 Material properties

Structural steel

The guidance given in EN 1994-1-1 relates to structural steel grades up to S460. For properties, reference is made to EN 1993-1-1.

Concrete

For structural concrete, EN 1994-1-1 refers to EN 1992-1-1 for properties but it relates to a narrower range of concrete strength classes than are given in EN 1992-1-1 (it omits the lowest and highest grades in EN 1992-1-1). See Section 5.2 for further comment on concrete grades.

Shear connectors

EN 1994-1-1 refers to EN ISO 13918 for headed stud shear connectors (actually it refers incorrectly to EN 13918, which is a different Standard). EN ISO 13918 covers a range of stud diameters from 10 mm to 25 mm and two materials – structural steel and stainless steel. In determining the design resistance, EN 1994-1-1 limits the material ultimate tensile strength to 500 N/mm². When specifying headed stud shear connectors, the designation 'SD' is used - for example: 'SD 19×100', which is a stud of 19 mm diameter and a nominal height of 100 mm.

Reinforcement

EN 1994-1-1, Section 3.2 refers to EN 1992-1-1 for the properties of reinforcing steel. However, it should be noted that EN 1994-1-1 permits the design value of the modulus of elasticity for reinforcing steel to be taken as equal to that for structural steel given in EN 1993-1-1 (i.e. 210 kN/mm² rather than 200 kN/mm²).

Profiled steel sheeting (decking)

EN 1994-1-1 refers to Sections 3.1 and 3.2 of EN 1993-1-3 for the material properties of profiled steel sheeting.

5.1.2 Structural analysis and stability

As in EN 1993-1-1, first order analysis can be used unless the effects of the deformed geometry significantly modify the structural behaviour, in which case either modified first order effects should be determined or a second order analysis carried out.

EN 1994-1-1 gives rules under four headings for the following types of global analysis:

- linear elastic analysis, in which allowance is made for cracking of concrete, creep and shrinkage
- non-linear global analysis, which generally follows the rules for plastic global analysis in EN 1993-1-1 and takes account of the behaviour of the shear connection
- linear elastic analysis with limited redistribution, which may be used where second order effects do not need to be considered
- rigid plastic analysis, for which limitations at plastic hinge locations are given.

Generally, plastic analysis is used as it enables more economic designs. For serviceability limit states, elastic analysis should be used, but where necessary, consideration of concrete cracking should be made.

5.1.3 Effective width

EN 1994-1-1 gives rules for determining the effective width of a concrete flange for determining the composite properties. The effective width is based on the longitudinal distance between zero moment positions, and varies along the width of the beam to take account of the build-up of shear close to the supports.

5.1.4 Section classification

The section classification in EN 1993-1-1 is adopted for composite sections. Where a steel element is attached to a reinforced concrete element, the classification of the element can, in some cases, be improved. Requirements for ductility of reinforcement in tension are given for Class 1 and Class 2 cross sections.

5.1.5 Modular ratio

For linear elastic analysis, the modular ratio for concrete is required. EN 1994-1-1 gives an expression that depends on the creep coefficient, as defined in EN 1992-1-1, and a factor that takes into account the type of loading.

5.1.6 Cross sectional resistance

Bending resistance

The design bending resistance of a composite section may be determined by elastic analysis and non-linear theory for any class of cross section; for Class 1 or Class 2 cross sections, rigid-plastic theory may be used.

Plastic resistance moments of composite sections may be determined either assuming full interaction between the steel and reinforced concrete or assuming partial shear connection (i.e. when the force transferred to the concrete is limited by resistance of the shear connectors). See comment on partial shear connection below.

Resistance to vertical shear

The resistance of a composite section to vertical shear is generally taken simply as the shear resistance of the structural steel section. Where necessary, the resistance of uncased webs to shear buckling should be determined in accordance with EN 1993-1-5 (see Section 4.2).

5.1.7 Shear Connection

Rules for the verification of the shear connection in composite beams are given in Section 6.6 of EN 1994-1-1. Detailed rules are only given for headed stud connectors. Dimension limits and rules for transverse reinforcement are given. Natural bond between the concrete and steel is ignored.

Design resistance of shear connectors

EN 1994-1-1 gives the design shear resistance of a headed stud connector as the smaller of the shear resistance of the stud and the crushing strength of the concrete around it. When used with profiled steel sheeting, a reduction factor, based on the geometry of the deck and the height of the stud, is used to reduce the resistance of the shear connectors. Stud connectors have sufficient ductility to develop ideal plastic behaviour, provided that certain limits are observed if there is only partial shear connection.

Partial shear connection

Limitations are given on the use of partial shear connection, i.e. for situations where the design shear resistance over a length of beam is insufficient to develop the full resistance of the composite beam.

Longitudinal shear resistance of concrete slabs

The longitudinal shear resistance of a slab is calculated using the procedure given in EN 1992-1-1. However, the shear planes that may be critical and the contributions from the reinforcement or the profiled steel sheeting (if the shear connectors are through-deck welded) are defined in EN 1994-1-1.

5.1.8 Serviceability limit states

As stated in Section 4.1.6, no serviceability limit state limits for vertical or horizontal deflections are given in EN 1993-1-1. However, Section 7.4 of EN 1994-1-1 gives details of the minimum reinforcement required to satisfy the crack width limits specified in EN 1992-1-1.

5.1.9 Connection design

For composite joints, such as where there is a double-sided beam-to-column joint and the composite slab is continuous, EN 1994-1-1 provides supplementary rules to those in EN 1993-1-8 to verify the connections. Rules are also given for column web panels in shear or transverse compression when encased in concrete.

5.2 EN 1992, Eurocode 2

EN 1992-1-1 gives generic design rules for concrete structures and should be used with parts of EN 1994 for steel and concrete composite structures.

5.2.1 Material properties

The material properties given in EN 1992-1-1 that are used for steel and concrete composite design are briefly discussed in this Section.

Concrete

Strength and mechanical properties of concrete for different strength classes are given in EN 1992-1-1 in Table 3.1 for normal concrete and in Table 11.3.1 for lightweight aggregate concrete. The concrete strength classes are based on characteristic cylinder strengths (f_{ck}), which are determined at 28 days.

Concrete designations are given typically as C25/30, where the cylinder strength is 25 MPa and the cube strength is 30 MPa. Properties are given for a range of lightweight aggregate concrete grades, for densities between 800 and 2000 kg/m^3; a typical designation is LC25/28.

Reinforcement

Material properties in EN 1992-1-1 apply to the following forms of reinforcement:

- Bars
- De-coiled rods
- Welded fabric
- Lattice girders.

The rules do not apply to specially coated bars.

As noted earlier, for design of composite structures, the modulus of elasticity for reinforcing steel may be taken as that for structural steel.

5.2.2 Reinforced concrete beams and slabs

Rules for the design of reinforced concrete beams and slabs are given in EN 1992-1-1 Section 6 for ULS verification and in Section 7 for SLS verification. Requirements for durability and cover to reinforcement are given in Section 4. Requirements for cover relate to exposure class and structural classification, both of which are defined in EN 1992-1-1.

6 BIBLIOGRAPHY

6.1 SCI and SCI/BCSA publications

The publications listed below are in accordance with Eurocodes and the UK National Annexes

1. Steel building design: Concise Eurocodes (P362),
   SCI, 2009
2. Steel building design: Design data (P363)
   SCI and BCSA, 2009
3. Steel building design: Worked examples – Open sections (P364)
   SCI, 2009
4. Steel building design: Medium-rise braced frames (P365)
   SCI, 2009
5. Steel building design: Worked examples – Hollow sections (P374)
   SCI, 2009
6. Steel building design: Fire resistance design (P375)
   SCI, 2009
7. Steel building design: Worked examples for students (P387)
   SCI, 2009
8. Joints in steel construction: Simple connections in accordance with Eurocode 3 (P358)
   SCI & BCSA, *to be published in 2010*
9. Steel building design: Composite members (P359)
   SCI, *to be published in 2010*
10. Steel building design: Stability of beams and columns (P360)
    SCI, *to be published in 2010*
11. Handbook of structural steelwork Eurocode Edition (P366)
    BCSA & SCI, *to be published in 2010*
12. Steel building design: Combined bending and torsion (P385)
    SCI, *to be published in 2010*

6.2 Eurocodes

The following Eurocode Parts are applicable for the design of steel-framed buildings, although not all will be required for a specific structure, depending on its use and form of construction.

In the UK they are published by BSI with a BSI prefix to the Standard number (e.g. BS EN 1990).

EN 1990 Eurocode – Basis of structural design

EN 1991 Eurocode 1: Actions on structures

EN 1991-1-1 Part 1-1: General actions. Densities, self-weight, imposed loads for buildings

EN 1991-1-2 Part 1-2: General actions. Actions on structures exposed to fire

EN 1991-1-3 Part 1-3: General actions. Snow loads

EN 1991-1-4 Part 1-4: General actions. Wind actions

EN 1991-1-5 Part 1-5: General actions. Thermal actions

EN 1991-1-6 Part 1-6: General actions. Actions during execution

EN 1991-1-7 Part 1-7: General actions. Accidental actions

EN 1992 Eurocode 2: Design of concrete structures

EN 1992-1-1 Part 1-1: General rules and rule for buildings

EN 1992-1-2 Part 1-2: General rules – Structural fire design

EN 1993 Eurocode 3: Design of steel structures

EN 1993-1-1 Part 1-1: General rules and rules for buildings

EN 1993-1-2 Part 1-2: General rules – Structural fire design

EN 1993-1-3 Part 1-3: General rules – Supplementary rules for cold-formed members and sheeting

EN 1993-1-5 Part 1-5: Plated structural elements

EN 1993-1-8 Part 1-8: Design of joints

EN 1993-1-9 Part 1-9: Fatigue

EN 1993-1-10 Part 1-10: Material toughness and through-thickness properties

EN 1993-1-12 Part 1-12: Additional rules for the extension of EN 1993 up to steel grades S700

EN 1994 Eurocode 4: Design of composite steel and concrete structures

EN 1994-1-1 Part 1-1: General rules and rules for buildings

EN 1994-1-2 Part 1-2: General rules – Structural fire design

National Annexes

The UK National Annexes to all the Structural Eurocodes listed above, were published by spring of 2009.

6.3 Published Documents

Published Documents that may be of help to building designers include:

PD 6688-1-1 Background paper to the UK National Annex to BS EN 1991-1-1

PD 6688-1-2:2007 Background paper to the UK National Annex to BS EN 1991-1-2, BSI, 2007

PD 6688-1-4 Background paper to the UK National Annex to BS EN 1991-1-4, Eurocode 1 Part 1-4

PD 6688-1-5 Background paper to the UK National Annex to BS EN 1991-1-5

PD 6688-1-7 Background paper to the UK National Annex to BS EN 1991-1-7

PD 6687:2006 Background paper to the UK National Annexes to BS EN 1992-1, BSI, 2006, (to be re-designated as PD 6687-1)

PD 6695-1-9:2008 Recommendations for the design of structures to BS EN 1993-1-9

PD 6695-1-10:2008 Recommendations for the design of structures to BS EN 1993-1-10

6.4 Execution Standard

EN 1090-2:2008 Execution of steel structures and aluminium structures – Part 2: Technical requirements for steel structures. Published Dec 2008 in UK by BSI with a BS prefix)

6.5 Product Standards

The following product standards are published in the UK by BSI with a BSI prefix to the Standard number (e.g. BS EN 10025-2).

EN 10025-2:2004 Hot rolled products of structural steels. Part 2: Technical delivery conditions for non-alloy structural steels

EN 10164:1993 Steel products with improved deformation properties perpendicular to the surface of the product. Technical delivery conditions

EN 10210-1:2006 Hot finished structural hollow sections of non-alloy and fine grain structural steels Part 1: Technical delivery requirements

EN 10219-1:2006 Cold formed welded structural hollow sections of non-alloy and fine grain steels. Part 1: Technical delivery conditions

EN ISO 1461:2009 Hot dip galvanized coatings on fabricated iron and steel articles – Specifications and test methods

EN ISO 13918:1998 Welding – Studs and ceramic ferrules for arc stud welding

6.6 Web sites

The following web sites offer information and guidance documents in relation to the Eurocodes and to steel design to the Eurocodes.

Access Steel

Web site: www.access-steel.com

Access Steel has been specifically tailored for construction professionals and their clients to offer guidance through project initiation, scheme development and detailed design. It is easily searchable and free to all registered users. It offers harmonised, quality assured information in English, French, German and Spanish, with comprehensive coverage of Single and Multi-storey Buildings and Residential Construction. Special attention is given to the new opportunities for Fire Safety Engineering in the Eurocodes.

The site also includes over 50 interlinked modules on the detailed design of elements, with step-by-step guidance, full supporting information and worked examples, to give a thorough understanding of how the Eurocodes should be used.

Eurocodes - Building the future

Web site: http://eurocodes.jrc.ec.europa.eu/

The web site is hosted by the Joint Research Centre of the EC Directorate General Enterprise & Industry.

In line with the Commission Recommendation, the purpose of the site is to collect and disseminate information on the EN Eurocodes which is deemed to:

- facilitate adoption, implementation and use of the EN Eurocodes
- increase awareness of the EN Eurocodes in the EU countries and internationally
- foster further harmonization and development of the EN Eurocodes.

The web site aims to engage all stakeholders in order to contribute in keeping the Eurocodes the most up-to-date usable codes of practice.

NCCI for design in UK

Web site: www.steel-ncci.co.uk

This website is referenced in the National Annex to BS EN 1993-1-1 and serves as a listing of non-contradictory complementary information for the design of steel structures in the UK. The NCCI references are associated with relevant clauses of the Standard and provide links to other resources. Where the NCCI is a public electronic resource, hyperlinks are provided.

APPENDIX A ULS combination of actions

Table A.1 presents values given in UK National Annexes for the partial, combination and reduction factors that should be applied to the variable actions when more than one independent variable action occur simultaneously. The table presents values for expressions 6.10, 6.10a and 6.10b for the STR and GEO ultimate limit states (STR and GEO limit states are discussed in Section 2.5).

See Section 2.5 for a discussion of design values, partial factors, factors on accompanying actions and reduction factors applied to permanent actions.

Table A.1 *Partial, combination and reduction factors for the STR and GEO ultimate limit states for buildings in the UK*

Expression	Unfavourable Permanent action	Unfavourable Variable actions		
	Self-weight	Imposed floor loads	Wind loads	Snow loads*
6.10	$\gamma_{G,j,sup} = 1.35$	$\gamma_{Q,1} = 1.5$	$\gamma_{Q,i}\psi_{0,i} = 1.5 \times 0.5 = 0.75$	$\gamma_{Q,i}\psi_{0,i} = 1.5 \times 0.5 = 0.75$
	$\gamma_{G,j,sup} = 1.35$	$\gamma_{Q,i}\psi_{0,i} = 1.5 \times 0.7 = 1.05$	$\gamma_{Q,1} = 1.5$	$\gamma_{Q,i}\psi_{0,i} = 1.5 \times 0.5 = 0.75$
	$\gamma_{G,j,sup} = 1.35$	$\gamma_{Q,i}\psi_{0,i} = 1.5 \times 0.7 = 1.05$	$\gamma_{Q,i}\psi_{0,i} = 1.5 \times 0.5 = 0.75$	$\gamma_{Q,1} = 1.5$
6.10a+	$\gamma_{G,j,sup} = 1.35$	$\boldsymbol{\gamma_{Q,1}\psi_{0,1} = 1.5 \times 0.7 = 1.05}$	$\gamma_{Q,i}\psi_{0,i} = 1.5 \times 0.5 = 0.75$	$\gamma_{Q,i}\psi_{0,i} = 1.5 \times 0.5 = 0.75$
	$\gamma_{G,j,sup} = 1.35$	$\gamma_{Q,i}\psi_{0,i} = 1.5 \times 0.7 = 1.05$	$\boldsymbol{\gamma_{Q,1}\psi_{0,1} = 1.5 \times 0.5 = 0.75}$	$\gamma_{Q,i}\psi_{0,i} = 1.5 \times 0.5 = 0.75$
	$\gamma_{G,j,sup} = 1.35$	$\gamma_{Q,i}\psi_{0,i} = 1.5 \times 0.7 = 1.05$	$\gamma_{Q,i}\psi_{0,i} = 1.5 \times 0.5 = 0.75$	$\boldsymbol{\gamma_{Q,1}\psi_{0,1} = 1.5 \times 0.5 = 0.75}$
6.10b	$\xi\gamma_{G,j,sup} = 0.925 \times 1.35 = 1.25$	$\gamma_{Q,1} = 1.5$	$\gamma_{Q,i}\psi_{0,i} = 1.5 \times 0.5 = 0.75$	$\gamma_{Q,i}\psi_{0,i} = 1.5 \times 0.5 = 0.75$
	$\xi\gamma_{G,j,sup} = 0.925 \times 1.35 = 1.25$	$\gamma_{Q,i}\psi_{0,i} = 1.5 \times 0.7 = 1.05$	$\gamma_{Q,1} = 1.5$	$\gamma_{Q,i}\psi_{0,i} = 1.5 \times 0.5 = 0.75$
	$\xi\gamma_{G,j,sup} = 0.925 \times 1.35 = 1.25$	$\gamma_{Q,i}\psi_{0,i} = 1.5 \times 0.7 = 1.05$	$\gamma_{Q,i}\psi_{0,i} = 1.5 \times 0.5 = 0.75$	$\gamma_{Q,1} = 1.5$

Note:

All factor values given above are taken from the National Annex to BS EN 1990.

Shaded boxes indicate the *'leading variable action'*.

Bold text indicates the '*main accompanying variable action'*.

The remaining variable actions are the *'other accompanying variable actions'*.

\+ The same values are obtained for each of the three variations of expression (6.10a) (i.e. when each variable action in turn is treated as the main accompanying action) because the UK National Annex specifies the same value for $\gamma_{Q,1}$ and $\gamma_{Q,i}$.

* $\psi_{0,1}$ and $\psi_{0,i}$ values for snow are for buildings at an altitude of less than 1000 m above mean sea level.