Department for
Communities and Local Government

Guide to the use of EN 1990 Basis of Structural Design

September 2006

Department for Communities and Local Government: London

On 5th May 2006 the responsibilities of the Office of the Deputy Prime Minister (ODPM) transferred to the Department for Communities and Local Government (DCLG)

Department for Communities and Local Government
Eland House
Bressenden Place
London
SW1E 5DU
Telephone: 020 7944 4400
Website: www.communities.gov.uk

Guide to use of EN 1990 April 2005
It should be noted that this guidance has been based on the latest published Eurocode; together with the latest published National Annex at the time of writing.

If you require this publication in an alternative format please email alternativeformats@communities.gsi.gov.uk

DCLG Publications
PO Box 236
Wetherby
West Yorkshire
LS23 7NB
Tel: 08701 226 236
Fax: 08701 226 237
Textphone: 08701 207 405
Email: communities@twoten.com
or online via the DCLG website: www.communities.gov.uk

September 2006

Product Code: 06 BD 04021 (b)

CONTENTS

1. Introduction

The project which led to the production of this report arose with the intention of producing a handbook to encourage the safe and consistent adoption of EN 1991-1 : Eurocode 1 - Actions on Structures: Part 1: General Actions, in the UK. The project was modified to consider only two specific sections of EN 1991-1, which were:

EN 1991 Actions on structures - Part 1.4: Wind Actions
EN 1991 Actions on structures - Part 1.7: Accidental actions

However, both of these sections require information from EN 1990 'Basis of Structural Design', hence EN 1990 also had to be considered.

Although the original intention had been to produce one handbook, it became apparent that the various parts of the Eurocode could not be treated in a consistent manner. For example, parts of EN 1991-1-4 can be compared with BS6399-2, but EN 1991-1-7 has no equivalent UK code; hence, it was felt appropriate to prepare separate reports for each section. This would also allow further parts of EN1991-1 to be considered later. The reports, which have been produced so far, are for EN 1990, EN 1991-1-4 and EN 1991-1-7.

An initial requirement was that the handbook should be concise, user friendly and summarise the major differences between EN1991-1 and existing UK codes. Therefore, information given in EN 1991 that does not conflict with UK codes is simply referenced and no explanation is given about its derivation. For this latter type of information, the reader is referred to the Thomas Telford publications on the Structural Eurocodes (www.eurocodes.co.uk).

Although several parts of EN1991 and their respective National Annexes are complete, others are still being processed. The current state of progress is given in Table 1. A consequence of starting the work before the codes with their National Annexes are published by BSI is that the work can only be based on the latest editions of the code, and some details may change when the Codes are finally issued.

Table 1 Current status of the various sections of EN 1991

Section	Title	Final text released by CEN	Anticipated publication date by BSI along with associated National Annex
EN 1990	Basis of structural design	April 2002	April 2004
EN 1991-1-1	Densities, self-weight and imposed loads	April 2002	April 2004
EN 1991-1-2	Actions of structures exposed to Fire	Nov. 2002	~ Nov 2004
EN 1991-1-3	Snow Loads	July 2003	~ Dec 2004
EN 1991-1-4	Wind Actions	~ May 2004	May 2006
EN 1991-1-5	Thermal Actions	Oct 2003	Oct 2005
EN 1991-1-6	Actions during execution	Sep 2004	Sep 2006
EN 1991-1-7	Accidental actions due to impact and explosion	Jun 2005	Dec 2007

A series of designer's guides on the various Eurocodes is being prepared by Thomas Telford and some user manuals are planned by the Institution of Structural Engineers (www.istructe.org.uk). It is recommended that these web pages be checked to obtain up-to-date information on the available publications

1.1 Eurocode terminology

Most of the definitions given in the Eurocodes derive from

- ISO 2394(1998) General principles on reliability for structures
- ISO 3898 (1997) Bases for design of structures -- Notations -- General symbols
- ISO 8930 (1987) General principles on reliability for structures -- List of equivalent terms

Users of BD 15 should refer to EN 1990 which provides a basic list of terms and definitions which are applicable to EN 1990 to EN 1999, thus ensuring a common basis for the Eurocode suite.

For the structural Eurocode suite, attention is drawn to the following key definitions, which may be different from current national practices:

- "Action" means a load, or an imposed deformation (e.g. temperature effects or settlement)
- "Effects of Actions" or "Action effects" are internal moments and forces, bending moments, shear forces and deformations caused by actions
- "Strength" is a mechanical property of a material, in units of stress
- "Resistance" is a mechanical property of a cross-section of a member, or a member or structure.
- "Execution" covers all activities carried out for the physical completion of the work including procurement, the inspection and documentation thereof. The term covers work on site; it may also signify the fabrication of components off site and their subsequent erection on site.

1.2 Eurocode symbols

The notation in the Eurocodes is based on ISO 3898.

There are important changes from previous UK notation. For example, the notation for the longitudinal axis is the x-x axis (previously the z-z axis), the major axis is the y-y axis (previously the x-x axis) and the minor axis is the z-z axis (previously the y-y axis).

Characteristic values of any parameter are distinguished by a subscript "k". Design values have the subscript "d".

NOTE: Symbols used in this document are generally defined in the text. Where this is not so, the meaning of a symbol can be obtained from the relevant Eurocode part covered by this Handbook.

1.3 Eurocode annexes

There are two categories of Annexes to the Structural Eurocodes. One type is labelled 'I' and is Informative (i.e. for information and not as a mandatory part of the code). The second type I labelled 'N' and is Normative (i.e. a mandatory part of the code). In their National Annex, a country can choose to make an Informative annex Normative if they so wish.

Chapter 2: EN 1990: Eurocode: Basis of Structural Design

2.1 Introduction

2.1.1 Objectives of EN 1990

EN 1990: Eurocode: Basis of structural design [1] is the head key code for the harmonised Structural Eurocodes. EN 1990 establishes for all the Structural Eurocodes the principles and requirements for safety and serviceability and provides the basis and general principles for the structural design and verification of buildings and civil engineering structures (including geotechnical aspects). EN 1990 gives guidelines for related aspects of structural reliability, durability and quality control. It is based on the limit state concept and used in conjunction with the partial factor method.

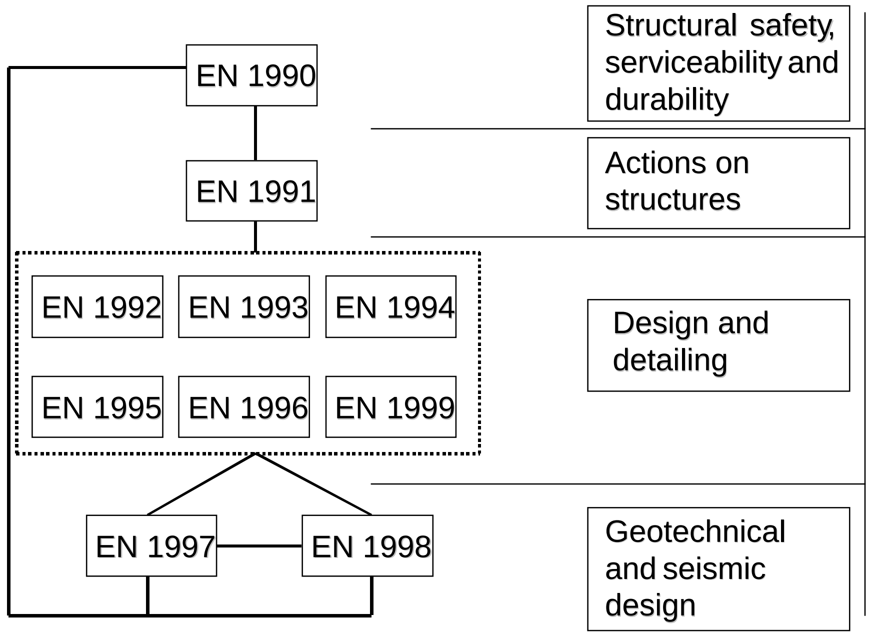

Figure 1: Links between Eurocodes

As shown in Figure 1, EN 1990 will be used with every Eurocode for the design of new structures, together with

- Eurocode 1: Actions on Structures, and
- The design Eurocodes (Eurocodes 2 to 9)

This is different to the situation adopted by British Standard Codes of Practice (e.g. BS 8110, BS 5950, BS 5628 etc.) because with the Eurocodes the requirements for achieving safety, serviceability and durability and the expressions for action effects for the verification of ultimate and serviceability limit states and their associated factors of safety are only given in EN 1990. Thus, the material independent rules given in EN 1990, including the selected expressions for combining the action effects must be used for each of the design Eurocodes and their parts.

2.1.2 Principal differences between EN 1990 and UK practice

This report explains the principal differences between EN 1990 and UK practice (i.e. the material independent clauses from Chapter 2 of BS 8110 and Chapter 2 of BS 5950 etc). The principal identified differences that will be explained are

- The contents and scope of EN 1990
- The requirements of EN 1990
- The design situations to consider for both the ultimate and serviceability limit states
- The representative values of the actions to use for the different design situations
- The expressions for combining the effects of actions
- The factors of safety to use for the appropriate design situations
- Choices made in the UK National Annex to EN 1990

Gulvanessian, Calgaro and Holicky provide a comprehensive description, background and commentary to EN 1990 [2].

2.2 The contents and scope of EN 1990

The contents of EN 1990 are given below. Under each Section heading a brief paragraph explains the contents of the appropriate Section in EN 1990 and reference to any topics covered in this report as follows:

Foreword

This covers

- the background to the Eurocode programme
- the status and field of application of the Eurocodes
- National standards implementing the Eurocodes
- links between Eurocodes and harmonised technical specifications for products
- additional information specific to EN 1990
- National Annexes to EN 1990

Section 1 General

The Scope of EN 1990 is defined, the differences in Principles and Rules of Application are described and terms and definitions and symbols applicable to EN 1990 are given.

Section 2 Requirements

The requirements of EN 1990 are given and these are discussed in section 2.3 of this report

Section 3 Principles of limit states

This section considers the general concept of design situations and limit states which are discussed in section 2.4.

Section 4 Basic variables

This section is concerned with the basic variables describing actions and environmental influences, material and product properties, and geometric data of construction works. This report describes the representative values of the actions to use for the different design situations in Section 2.5.

Section 5 Structural analysis and design assisted by testing

This section is concerned with the modelling of building and civil engineering structures for the purpose of determining action effects and resistance.

Section 6 Verification by the partial factor method

This section is concerned with the verification of building structures and civil engineering works using the partial factor method. It is applicable to all types of structures and is complemented by a series of Annexes which apply to particular types of structure. Section 2.6 of this Report describes the different expressions for combining the effects of actions.

Annex A1 (N) Application for buildings

This annex is concerned with the definition of combination of actions and requirements for the verification of building structures. It contains all the clauses through which national choice is allowed through the National Annex to EN 1990. Section 2.7 of this Report describes the recommended values for the partial factors for actions in EN 1990 and compares these with BS Codes of Practice. Section 2.8 of this Report describes the choices made in the UK National Annex to EN 1990.

Annex A2 (N) is concerned with bridges. For other types of structure further Annexes, also designated with an 'A' will follow.

Annex B (I) Management of structural reliability for construction works

This is concerned with the management of structural reliability...

Annex C (I) Basis for partial factor design and reliability analysis

This annex is concerned with the basis of partial factor design and with the general concepts of reliability analysis.

Annex D (I) Design assisted by testing

This considers design assisted by testing i.e. the determination of the characteristic or the design value of a single material property or of a resistance model from tests.

2.3 The requirements of EN 1990

Section 2 of EN 1990 is concerned with the requirements of EN 1990 which are:

- Fundamental requirements
- Reliability differentiation
- Design working life
- Durability
- Quality Assurance

Each of the requirements is briefly described below together with any differences from the BSI codes.

2.3.1 Fundamental Requirements

The fundamental requirements, concerning safety, serviceability, fire and robustness, stipulate that:

a) a structure shall be designed and executed in such a way that it will, during its intended life with appropriate degrees of reliability and in an economic way:

- remain fit for the use for which it is required (serviceability requirement); and
- sustain all actions and influences likely to occur during execution and use (safety requirement);

b) In the case of fire, the structural resistance shall be adequate for the required period of time (fire resistance requirement);

c) a structure shall be designed and executed in such a way that it will not be damaged by events such as explosion, impact or consequences of human errors, to an extend disproportionate to the original cause (robustness requirement). EN 1990 gives ways of avoiding or limiting potential damage.

The Fundamental Requirements relate very closely to the requirements in Schedule A of the Building Regulations used in the UK.

2.3.2 Reliability Differentiation

Design and execution according to the suite of the Eurocodes, together with appropriate quality control measures will ensure an appropriate degree of reliability for the majority of structures. Structures with very high consequences of failure will need additional consideration (e.g. very stringent quality control measures). EN 1990 provides guidance for adopting a different level of reliability (reliability differentiation) for structural safety or serviceability.

Reliability differentiation is a concept which is not covered by BSI codes. It will allow for the designer, with the agreement of the appropriate competent authority, to increase or lower the level of reliability based on quality control regimes adopted during the design and execution stages and the consequences of failure of a structure or an element. EN 1990 gives further guidance in an Informative Annex "Management of Structural Reliability for Construction works". A paper by Calgaro and Gulvanessian describes the management of structural reliability in EN 1990 [3].

2.3.3 Design Situations

EN 1990 stipulates that a relevant design situation is selected taking account of the circumstances in which the structure may be required to fulfil its function. For the safety requirement in 2.3.1, EN 1990 classifies design situations for ultimate limit state verification as follows:

- persistent situations (conditions of normal use);
- transient situations (temporary conditions e.g. during execution);
- accidental situations; and
- seismic situations.

For the serviceability requirement in 2.3.1, the design situations for serviceability limit state verifications relate to function, comfort and appearance (see 2.6.2).

The classification is more precise than that in the BS codes of practice; each design situation in EN 1990 uses different representative values for characteristic actions depending on whether the action is leading or accompanying. See Section 2.4.

2.3.4 Design Working Life

In EN 1990, the design working life is the assumed period for which a structure is to be used for its intended purpose with anticipated maintenance but without major repair being necessary. Table 2, taken from the UK National Annex for EN 1990, gives indicative design working life classifications.

Table 2 – Indicative Design Working Life

Design working life category	Indicative design working life (years)	Examples
1	10	Temporary structures [(1)]
2	10 to 30	Replaceable structural parts, e.g. gantry girders, bearings
3	15 to 25	Agricultural and similar structures
4	50	Building structures and other common structures, not listed elsewhere in this table
5	120	Monumental building structures, highway and railway bridges, and other civil engineering structures

[(1)] Structures or parts of structures that can be dismantled with a view of being re-used should not be considered as temporary

BSI codes do not have a design working life requirement for buildings. The requirement is useful for

- The selection of design actions
- Consideration of material property deterioration
- Life cycle costing
- Evolving maintenance strategies

Buildings subject to Building Regulations, hospitals, schools etc will be in category 4.

2.3.5 Durability

EN 1990 stipulates that the structure needs to be designed so that deterioration over its design working life does not impair the performance of the structure. The durability of a structure is its ability to remain fit for use during the design working life given appropriate maintenance.

EN 1990 aims to help the designer by identifying items that need to be allowed for during the design stage.

A structure should be designed in such a way, and/or provided with protection so that no significant deterioration is likely to occur within the period between successive inspections. Critical parts of the structure need to be available for inspection, without complicated dismantling. Other interrelated factors that need to be taken into account to ensure an adequately durable structure are given below:

- The intended and future use of the structure
- The required performance criteria
- The expected environmental influences
- The composition, properties and performance of materials
- The choice of a structural system
- The shape of members, structural detailing, and buildability
- The quality of workmanship and level of control
- The particular protective measures
- The maintenance during the intended life

These factors are expanded by Gulvanessian, Calgaro and Holicky.[2]

2.3.6 Quality Assurance

EN 1990 stipulates that appropriate quality assurance measures should be taken in order to provide a structure, which corresponds to the requirements and to the assumptions made in the design. These measures should include organisational measures and controls at the stages of design, execution, use and maintenance.

2.4 The design situations to consider for both the ultimate and serviceability limit states

2.4.1 Design Situation

In EN 1990, design situations are selected, for both the ultimate and serviceability limit states. The selected design situations are chosen so that they are sufficiently severe and so varied as to encompass all conditions which can reasonably be foreseen to occur during the execution and use of the structure.

2.4.2 Design Situations for Ultimate Limit State Verifications

EN 1990 classifies these as follows.

- transient design situations which refer to temporary conditions applicable to the structure, e.g. during execution or repair
- persistent design situations, which refer to the conditions of normal use
- accidental design situations, which refer to exceptional conditions applicable to the structure or to its exposure, e.g. to fire, explosion, impact or the consequences of localised failure
- seismic design situations, which refer to conditions applicable to the structure when subjected to seismic events

2.4.3 Design situations for Serviceability limit states

The design situations for serviceability limit states verifications in EN 1990 concern:

- the functioning of the structure or structural elements under normal use
- the comfort of people
- the appearance of the construction works

There are differences between the concept of the design situations approach in EN 1990 and the approach used in BSI codes. In the verification of serviceability limit states in EN 1990, separate load combination expressions are used depending on the design situation being considered. For each of the particular design situations an appropriate representative value for an action is used. (see 2.5)

2.5 The representative values of the actions to be used for the different design situations

In addition to the characteristic values of actions which are similar to the BSI definition, other representative values are specified in EN 1990 for variable and accidental actions. Three representative values commonly used for variable actions are the combination value $\psi_0 Q_k$, the frequent value $\psi_1 Q_k$ and the quasi-permanent value $\psi_2 Q_k$. The factors ψ_0, ψ_1 and ψ_2 are reduction factors of the characteristic values of variable actions, but they have different meanings.

For the persistent and transient design situations for ultimate limit states and for the characteristic (rare) combinations of serviceability limit states, only the non-leading variable actions may be reduced using the ψ_o coefficients. In other cases (for accidental design situation and combinations of serviceability limit states), the leading as well as accompanying actions may be reduced using the appropriate ψ coefficients (see Table 3).

Table 3 Application of coefficients ψ_0, ψ_1 and ψ_2 for leading and non-leading variable actions at ultimate and serviceability limit states, '×' means not applied

Limit State	Design Situation or Combination	Combination value ψ_0	Frequent value ψ_1	Quasi-permanent value ψ_2
Ultimate	Persistent and Transient	non-leading	×	×
	Accidental	×	leading	leading and non-leading
	Seismic	×	×	all variable actions
Serviceability	Characteristic	non-leading	×	×
	Frequent	×	leading	non- leading
	Quasi-permanent	×	×	all variable actions

Values for the three coefficients ψ_0, ψ_1 and ψ_2 are given in the BSI National Annex A to EN 1990. [4]

The combination value $\psi_0 Q_k$, the frequent value $\psi_1 Q_k$, and the quasi-permanent value $\psi_2 Q_k$ are described in Table 4 and shown schematically in Figure 2, and explained below.

Table 4

Representative values of actions

	Permanent actions	Variable actions	Accidental actions	Seismic actions
Characteristic value	G_k	Q_k		A_{Ek} or
Nominal value			A_d	$A_{Ed} = \gamma_I A_{Ek}$
Combination value		$\psi_0 Q_k$		
Frequent value		$\psi_1 Q_k$		
Quasi-permanent value		$\psi_2 Q_k$		

The combination value $\psi_0 Q_k$ is associated with the combination of actions for ultimate and irreversible serviceability limit states (e.g. functionality of fittings with brittle behaviour) in order to take account of the reduced probability of simultaneous occurrence of the most unfavourable values of several independent actions (i.e. applied to the characteristic value of all accompanying actions).

The frequent value $\psi_1 Q_k$ is primarily associated with the frequent combination in the serviceability limit states, but it is also used for verification of the accidental design situation of the ultimate limit states (e.g. everyday office use). In both cases, the reduction factor ψ_1 is applied as a multiplier of the leading variable action. In accordance with EN 1990, the frequent value $\psi_1 Q_k$ of a variable action Q is determined so that the total time, within a chosen period of time, during which $Q > \psi_1 Q_k$ is only a specified (small) part of the period, or the frequency of the event $Q > \psi_1 Q_k$ is limited to a given value. The total time for which $\psi_0 Q_k$ is exceeded is equal to the sum of time periods ψt_1, ψt_2, ... shown in Fig. 2 by continuous sections of the horizontal line indicating the frequent value $\psi_0 Q_k$.

According to EN 1990 the value 0,01 of the reference period is recommended.

The **quasi-permanent values** $\psi_2 Q_k$ **are mainly used** in the assessment of long-term effects, (e.g. cosmetic cracking of a slab). They are also used for the representation of variable actions in accidental and seismic combinations of actions (ultimate limit states) and for verification of frequent and quasi-permanent combinations (long term effects) of serviceability limit states.

In accordance with EN 1990, the quasi-permanent value $\psi_2 Q_k$ is defined so that the total time, within a chosen period during which it is exceeded, that is when $Q > \psi_2 Q_k$, is a considerable part (0,5) of the chosen period of time. The value may also be determined as the value averaged over the chosen period of time. The total time of $\psi_2 Q_k$ being exceeded is equal to the sum of periods, shown in Fig. 2 by the continuous sections of the horizontal line indicating the quasi permanent value $\psi_2 Q_k$.

The representative values $\psi_0 Q_k$, $\psi_1 Q_k$ and $\psi_2 Q_k$ and the characteristic values are used to define the design values of the actions and the combinations of actions as explained in Section 2.6.

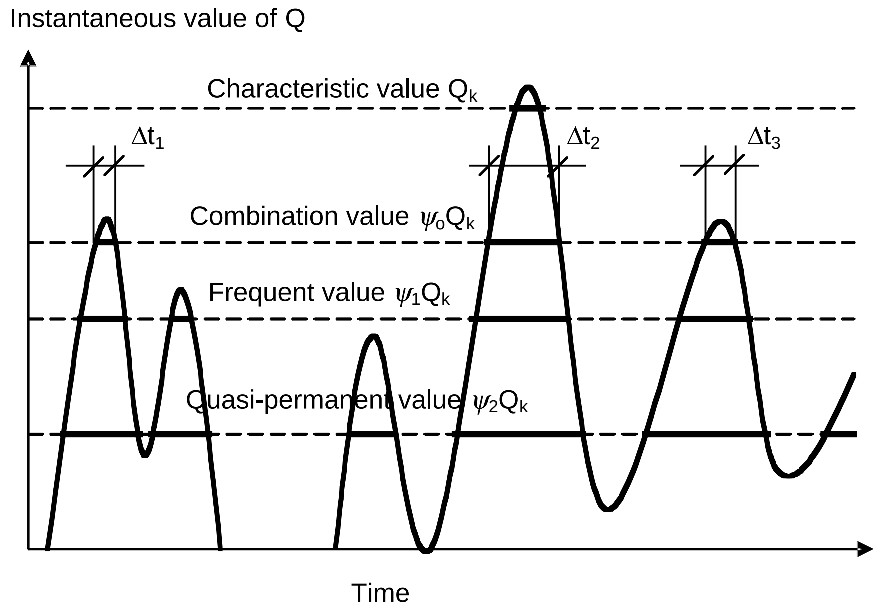

Figure 2: Diagrammatical representation of representative values for actions

2.6 The expressions for combining the effects of actions

2.6.1 Load combination expressions in EN 1990 for the verification of ultimate limit states for the transient and persistent design situations

EN 1990 specifies three alternative sets of expressions, from which a choice may be made by the National Annex (see 2.8) for the determination of action effects (Expression (6.10; (6.10a) and (6.10b); and (6.10a modified) & (6.10b)) for the persistent and transient design situations [3] to be used together with EN 1991 and the design Eurocodes for ultimate limit state verification.

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

The procedure using expression (6.10) is denoted as Case A in this document

(ii) or the less favourable of the two following expressions:

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

The procedure using expressions (6.10a) and (6.10b) is denoted as Case B.

(iii) or Expression 6.10a above modified to include permanent actions only and Expression 6.10b, as shown below

$$\begin{cases}\sum_{j\geq 1}\gamma_{G,j}G_{k,j}\text{"+"}\gamma_P P\text{"}\\ \sum_{j\geq 1}\xi_j\gamma_{G,j}G_{k,j}\text{"+"}\gamma_P P\text{"+"}\gamma_{Q,1}Q_{k,1}\text{"+"}\sum_{i>1}\gamma_{Q,i}\psi_{0,i}Q_{k,i}\end{cases}$$

The procedure using expression (6.10a modified) & (6.10b)) is denoted as Case C.

where:

"+"	Implies "to be combined with"
Σ	Implies "the combined effect of"
ξ	Is a reduction factor for unfavourable permanent actions 'G'

The above procedure is different to the BSI procedures. See 2.7, which also gives a comparison of partial factors for actions between EN 1990 and BSI.

The expressions for the accidental design situation given in EN 1990 basically use the same concept as BSI codes for the accidental action but accompanying loads are treated as above.

2.6.2 Load combination expressions in EN 1990 for the verification of serviceability limit states

As mentioned earlier, EN 1990 gives guidance on the following serviceability limit states verifications:

- the functioning of the structure or structural elements under normal use
- the comfort of people
- the appearance of the construction works

This is different from the concept of BSI codes.

In the verification of serviceability limit states in EN 1990, separate load combination expressions are used depending on the design situation being considered. For each of the particular design situations an appropriate representative value for an action is used.

For the serviceability limit states verification, EN 1990 recommends the three combinations below to be investigated: EN 1990 gives three expressions for serviceability design, characteristic, frequent and quasi-permanent.

a) The characteristic (rare) combinations used mainly in those cases when exceedance of a limit state causes a permanent local damage or permanent unacceptable deformation.

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

b) The frequent combination is used mainly in those cases when exceedance of a limit state causes local damage, large deformations or vibrations which are temporary.

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

c) The quasi-permanent combination is used mainly when long term effects are of importance.

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

EN 1990 states that the serviceability criteria should be specified for each project and agreed with the client.

2.7 The partial factors to use for the appropriate design situations

2.7.1 Ultimate limit state verifications

2.7.1.1 *Partial factors and reduction coefficients in EN 1990*

The partial factors and reduction coefficients γ, ψ and ξ recommended in EN 1990 [1] for ultimate limit state verification are summarized in Table 5.

Table 5: Partial and reduction factors for unfavourable actions (EN 1990).

Action	Partial factors γ	Combination factor ψ	Reduction factor ξ
Permanent *G*	1,35	1,0	0.85
Imposed *Q*	1,5	0,7*	-
Climatic W	1,5	0,5 - 0,7	-

* ψ = 1 for storage areas

Expression (6.10) can be simplified to

1,35*G* + 1,5*Q* considering one variable action *Q*; and

1,35*G* + 1,5*Q* + 0,75*W* considering two variable actions with the imposed action leading and the wind action accompanying.

2.7.1.2 *Load combination expressions in BS Codes of Practice (partial factors)*

The expressions used in the BSI codes are different in principle to Expression 6.10 of EN 1990 as BSI do not use the ψ concept. The partial factors used, see Table 6, differ from those used in EN 1990.

Table 6: Partial factors (BS 5628, BS 5950, and BS 8110).

Action	Combination of G and Q γ	Combination of G and W γ	Combination of G, Q and W γ
Permanent *G*	1,4	1,4	1,2
Imposed *Q*	1,6	-	1,2
Climatic *W*	-	1,4	1,2

2.7.2 Serviceability limit state verifications

For both EN 1990 and BSI verifications, γ = 1 is taken. However, in EN 1990 the characteristic value is reduced by an appropriate value of ψ depending on the design situation being used. In BSI codes, the characteristic loads are not reduced.

2.8 Choices made in the UK National Annex to EN 1990

2.8.1 Choice of NDPs for the BSI National Annex to EN 1990 for ultimate limit states verification

EN 1990 allows through National Determined Parameters (NDPs) and the National Annexes for

- The choice of which of the three combination expressions given in 2.6.1 to use, and
- The specification of appropriate safety factors (γ) and combination factors (ψ) and (ξ), for actions.

These should be used for the design of buildings in the UK.

2.8.1.1. ***The choice of which of the three combination expressions given in 2.6.1 to use and the specification of appropriate partial factors (γ) and combination coefficients (ψ) and (ξ), for actions.***

a) Combination with one variable action

A comparison of the EN 1990 combination rules, A (i.e. expression 6.10); B (i.e. expressions 6.10a and 6.10b) and C (i.e. modified expressions 6.10a and 6.10b) with the BSI rules (i.e. BS 8110, BS 5950 etc), is shown in Figure 2.4. In Figures 2.4 to 2.6 β is the reliability index (see Annex C of EN 1990) and χ is the ratio of variable loads to total loads. In this case the imposed load Q acts alone with the permanent actions and the recommended values for γ and ψ are those recommended in EN 1990 Annex A

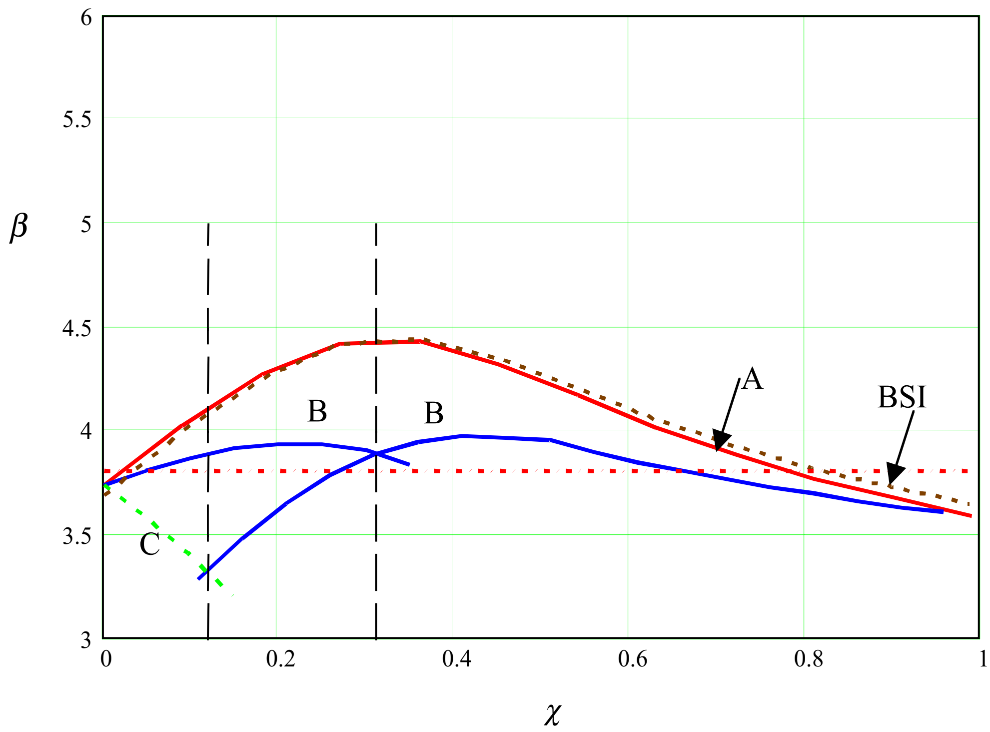

Figure 2.4: Variation of reliability index β with χ for EN 1990 combination rules A, B and C, (γ_R = 1,15, γ_G = 1,35, γ_Q = 1,5), and BSI rules (γ_R = 1,10, γ_G = 1,4, γ_Q = 1,6), k = 0 (i.e. one variable action). (N.B. $\chi = (Q_k+W_k)/(G_k+Q_k+W_k)$, $k = W_k/Q_k$)

b) Combination with two variable actions

A comparison of the EN 1990 combination rules, A (i.e. expression 6.10); B (i.e. expressions 6.10a and 6.10b) and C (i.e. expressions 6.10a and 6.10b) with the BSI rules (i.e. BS 8110, BS 5950 etc), are shown in Figure 2.5. In this case the imposed load Q together with the wind load W acts with the permanent actions, and the recommended values for γ and ψ are those given in EN 1990 Annex A

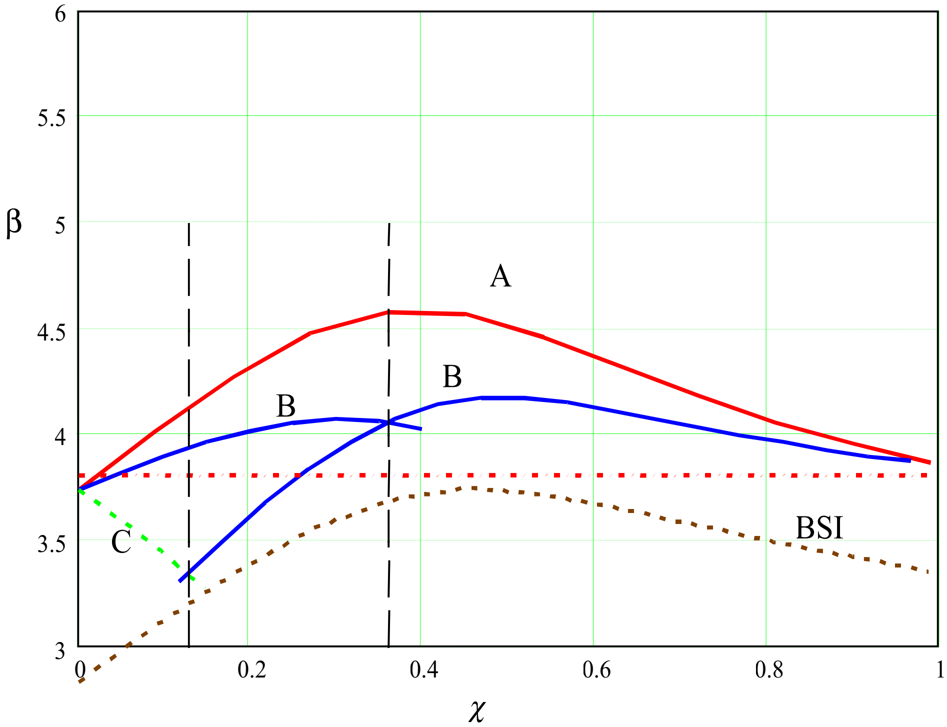

Figure 2.5. Variation of reliability index β with χ for the EN combination rules A, B and C, (γ_R = 1,15, γ_G = 1,35, γ_Q = 1,5, γ_W = 1,5, ψ_W = 0,5), and the BSI rules (γ_R = 1,10, γ_G = 1,2, γ_Q = 1,2, γ_W = 1,2) for k = 0,25 (two variable actions). (N.B. $\chi = (Q_k+W_k)/(G_k+Q_k+W_k)$, $k = W_k/Q_k$)

c) Effects of varying ξ

The effect on β on varying ξ from 0,85 to 0,95 in expression (6.10a) and (6.10b) is shown in Figure 2.6.

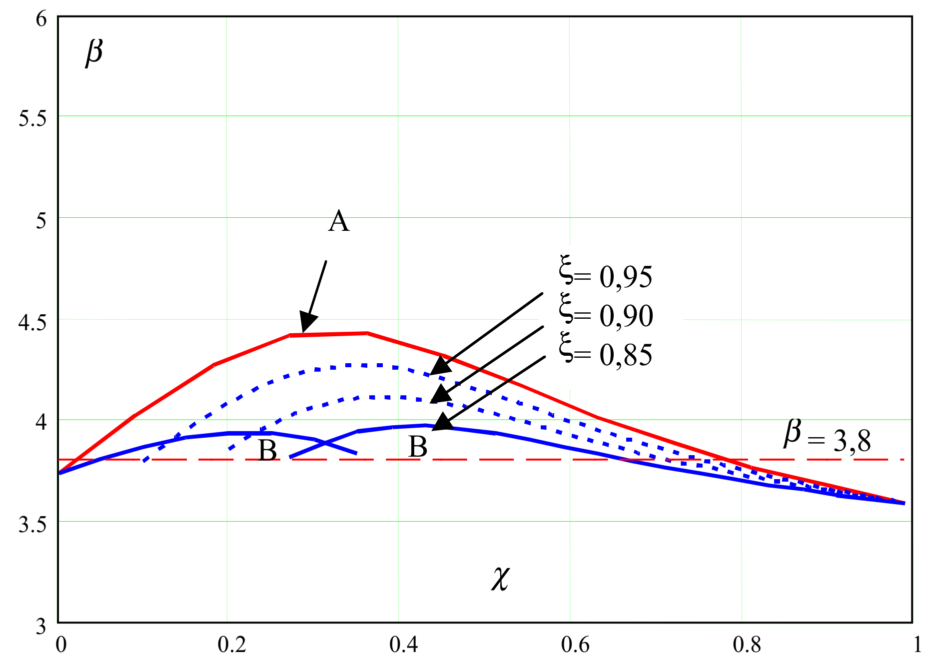

Figure 2.6: Variation of reliability index $\boldsymbol{\beta}$ with $\boldsymbol{\chi}$ for EN 1990 combination rules A (γ_R = 1,15, γ_G = 1,35, γ_Q = 1,5) and B (γ_R = 1,15, γ_G = 1,35, γ_Q = 1,5, $\boldsymbol{\xi}$ = 0,85, 0,90, 0,95). k = 0 (One variable action) (N.B. $\chi = (Q_k+W_k)/(G_k+Q_k+W_k)$, $k = W_k/Q_k$)

2.8.1.2 Observations from Figures 2.4, 2.5 and 2.6

a) The adoption of combination rule A (i.e. expression 6.10 of EN 1990), using the EN 1990 recommended values for partial safety, and combination factors will produce a closely comparable reliability to that attained in the UK, when one variable action is considered in combination. See Figure 2.4.

b) The reliability levels when considering two variable actions acting in combination with the permanent actions is much higher for EN 1990, rules A, B, and C than that obtained by the BSI codes. The BSI recommendation of using identical partial factors (1,2) for the permanent action and for each of the variable actions has been shown to give a lower level of reliability than all three EN 1990 cases.

c) Figures 2.4 and 2.5 indicate that Case A (expression 6.10) does not produce a consistent level of safety for the complete range of χ. Adopting Case B (expression 6.10a and 6.10b) would seem to provide a more consistent level, but a lower level of safety when considering one variable action and a higher level of safety when considering more than one variable action, than that presently found in the UK.

d) Table 7 considers the use of cases A, B and C with recommended γ, ψ and ε values from EN 1990.

Table 7: Comparison of EN 1990, Cases A, B and C with UK practice

Objective	Case A (exp. 6.10)	Case B (exp 6.10a, 6.10b)	Case C ((6.10a (mod), 6.10b))
Same level of reliability between EN 1990 and BS codes? (as measured by index β)	Yes	No 10-15% lower for χ between 0,15 and 0,8	No 10-20% lower for χ between 0,15 and 0,8
Consistency of reliability for range of $\boldsymbol{\chi}$	No Higher reliability for χ between 0,2 and 0,6	Yes	No Lower reliability for $\chi < 0,3$
Usability: EN 1990 rules vs. BSI rules	As for UK codes	More complicated than UK codes Problems envisaged for sub-structures	Slightly more complicated than UK codes. Problems envisaged for sub-structures
Economy Considering action effects only for a given resistance	As for UK practice	Greater economy for χ between 0,15 and 0,6	Much greater economy for χ between 0,15 and 0,6

Note: Whilst β may be only "10-15% lower", this reflects a factor of 40 times in terms of the probability of failure.

e) Figure 2.6 shows the variation of β for the complete range of χ for:

- Combination A, with γ_G = 1,35 and γ_Q = 1,5
- Combination B, with γ_G = 1,35 γ_Q = 1,5 and ξ = 0,85
- Combination B, with γ_G = 1,35 γ_Q = 1,5 and ξ = 0,90
- Combination B, with γ_G = 1,35 γ_Q = 1,5 and ξ = 0,95

Comparing the three curves for combinations B with combination A (with γ_G = 1,35 and γ_Q = 1,5), (NB. combination A also agrees with UK practice) shows that :

- Use of combination B with ξ = 0,925 will provide a reduction of β of about 5% between χ of 0,2 and 0,5, and better consistency of reliability compared to combination A.

A comprehensive study of these issues is given in [5].

2.8.1.3 *Conclusions and decisions for combination and partial factors to be adopted in the BSI National Annex*

Based on the considerations discussed above and considering in particular the:

- levels of reliability currently attained in the UK; and
- usability, both for the super-structure and the sub-structure.

The UK National Annex has adopted

- expression 6.10 with γ_G = 1,35 and γ_Q = 1,5, or
- expression 6.10a and 6.10b with γ_G = 1,35 and γ_Q = 1,5 and ξ = 0,925.

(i.e. either may be used for the design)

For the accidental design situations, expression (6.11b) of EN 1990 has been adopted in the BSI National Annex and $\psi_{1,1}$ is chosen for the loading variable action.

2.8.2 Choice of NDPs for the BSI National Annex to EN 1990 for serviceability limit state verification.

The BSI National Annex adopts the expressions (6.14b) and (6.15b) and (6.18b) with γ=1, and the ψ values given in the National Annex (see 2.6.2)

3. References

1. EN 1990: Eurocode: Basis of Structural Design: BSI April 2002

2. Gulvanessian H, Calgaro J-A, Holicky M: Designers' Guide to EN 1990: Eurocode: Basis of Structural Design. Thomas Telford, 2002.

3. Calgaro J-A, Gulvanessian H: Management of reliability and risk in the Eurocode system. Conference – Safety, Risk and Reliability, Malta – Trends in Engineering. IABSE 2001.

4. National Annex to BSEN 1990 : BSI - 2005