EN 1990: Eurocode: Basis of Structural Design

The Key Head Eurocode

An Innovative Structural Safety Code Of Practice

EN 1990 – Sections 1 and 2

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EN 1990 : EUROCODE: BASIS OF STRUCTURAL DESIGN

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EN 1990 : EUROCODE: BASIS OF STRUCTURAL DESIGN

1.1 Scope

(1) EN 1990 establishes Principles and requirements for the safety, serviceability and durability of structures, describes the basis for their design and verification and gives guidelines for related aspects of structural reliability.

(2) EN 1990 is intended to be used in conjunction with EN 1991 to EN 1999 for the structural design of buildings and civil engineering works, including geotechnical aspects, structural fire design, situations involving earthquakes, execution and temporary structures.

NOTE For the design of special construction works (*e.g.* nuclear installations, dams, etc.), other provisions than those in EN 1990 to EN 1999 might be necessary.

(3) EN 1990 is applicable for the design of structures where other materials or other actions outside the scope of EN 1991 to EN 1999 are involved.

(4) EN 1990 is applicable for the structural appraisal of existing construction, in developing the design of repairs and alterations or in assessing changes of use.

NOTE Additional or amended provisions might be necessary where appropriate.

1.3 Assumptions

(1) Design which employs the Principles and Application Rules is deemed to meet the requirements provided the assumptions given in EN 1990 to EN 1999 are satisfied (see (2)).

(2) The general assumptions of EN 1990 are:

- **the choice of the structural system and the design of the structure is made by appropriately qualified and experienced personnel;**
- **execution is carried out by personnel having the appropriate skill and experience;**
- **adequate supervision and quality control is provided in design offices and during execution of the work, i.e. factories, plants, and on site;**

1.3 Assumptions (cont.)

- the construction materials and products are used as specified in EN 1990 or in EN 1991 to EN 1999 or in the relevant execution standards, or reference material or product specifications;
- the structure will be adequately maintained;
- the structure will be used in accordance with the design assumptions.

NOTE There may be cases when the above assumptions need to be supplemented.

1.4 Distinction between Principles and Application Rules

- The Principles (letter P) comprise :
  - **general statements and definitions for which there is no alternative, as well as**
  - **requirements and analytical models for which no alternative is permitted unless specifically stated.**
- It is permissible to use alternative design rules different from the application rules given in EN 1990, provided that it is shown that the alternative rules accord with the relevant principles and are at least equivalent with regard to resistance, serviceability and durability which would be achieved for the structure using Eurocodes.

NOTE 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. When EN 1990 is used in respect of a property listed in an Annex Z of a product standard or an ETAG, the use of an alternative design rule may not be acceptable for CE marking.

1.5 Definitions

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.

1.6 Symbols

Some Important Terms

Actions (*F*)

- Permanent Actions (*G*)
- Variable Actions (*Q*)
- Accidental Actions (*A*)
- Seismic Action (A_e)

Values of Actions

Representative Values of Actions

- Characteristic Value (Q_k)
- Combinations Value of a Variable Action ($\psi_0 Q_k$)
- Frequent Value of a Variable Action ($\psi_1 Q_k$)
- Quasi-permanent Value of a Variable Action ($\psi_2 Q_k$)

THE REQUIREMENTS

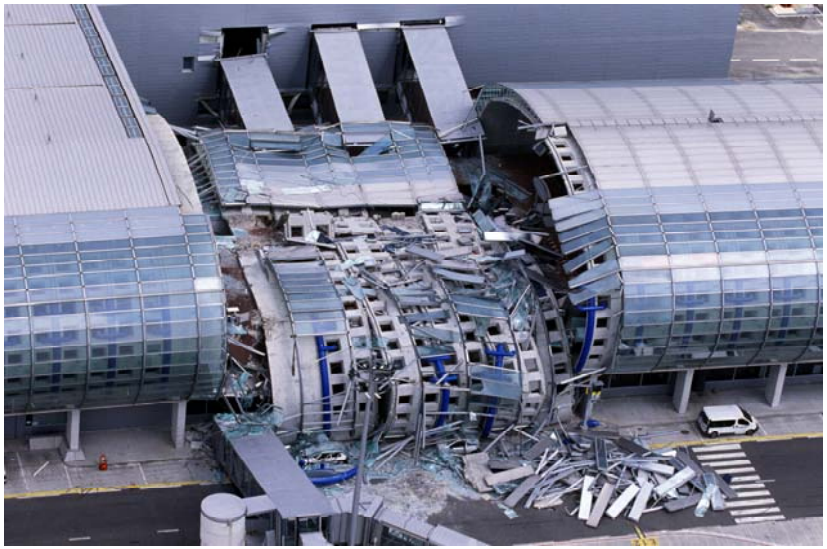
Fundamental requirements (safety; serviceability; robustness and fire)
Reliability differentiation
Design working life
Durability
Quality Assurance

EN 1990 : EUROCODE: BASIS OF STRUCTURAL DESIGN

The fundamental requirements in EN 1990 for the reliability of construction works include :

Structural safety: 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 sustain all actions likely to occur during execution and use. Safety of people, the structure and contents

Serviceability: 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 Functioning, comfort and appearance of the structure



The fundamental requirements:

Robustness

A structure shall be designed and executed in such a way that it will not be damaged by events such as

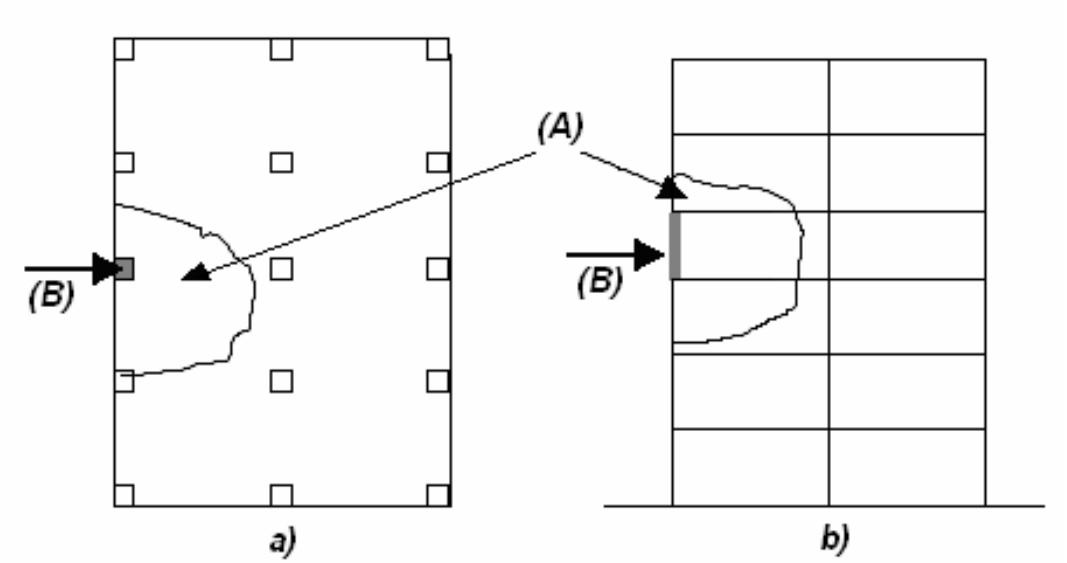
- Explosions
- Impact and
- Consequences of human errors

to an extent disproportionate to the original cause

Note: The events to be taken into account are those agreed for an individual project with the client and the relevant authority

Explosion at Ronan Point 1968

Robustness - Limits of admissible damage



a) is the plan
b) is the elevation

***(A)* is:**

- **15% of the floor area or**
- **100m2 whichever is the smaller, in each of two adjacent storeys**

***(B)* : Notional columns to be removed**

Robustness of Buildings and Civil Engineering Works

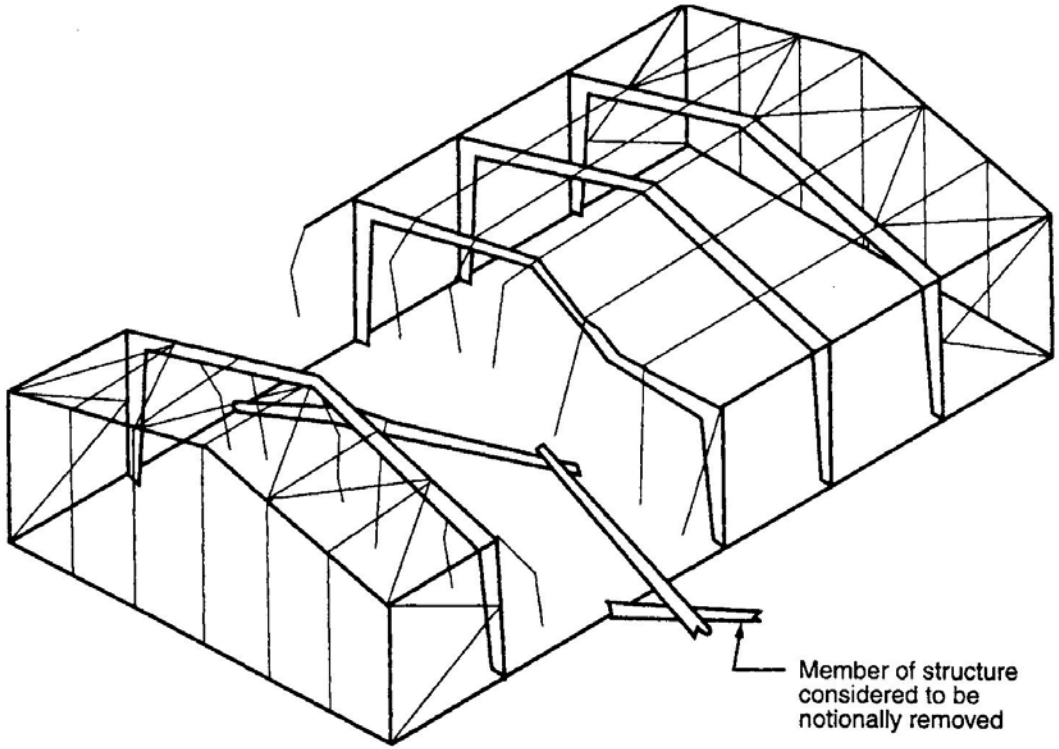
Limiting potential damage from identified hazards

EN 1990 gives principles for limiting potential damage by a number of means including:

- **avoiding, eliminating or reducing the hazards to which the structure can be subjected;**
- **selecting a structural form which has low sensitivity to the hazards considered;**
- **selecting a structural form and design that can survive adequately the accidental removal of an individual member or a limited part of the structure, or the occurrence of acceptable localised damage;**
- **avoiding as far as possible structural systems that can collapse without warning;**
- **tying the structural members together.**

EN 1990 : EUROCODE: BASIS OF STRUCTURAL DESIGN

Robustness: Acceptable extent of collapse in the event of a local failure in a large span building



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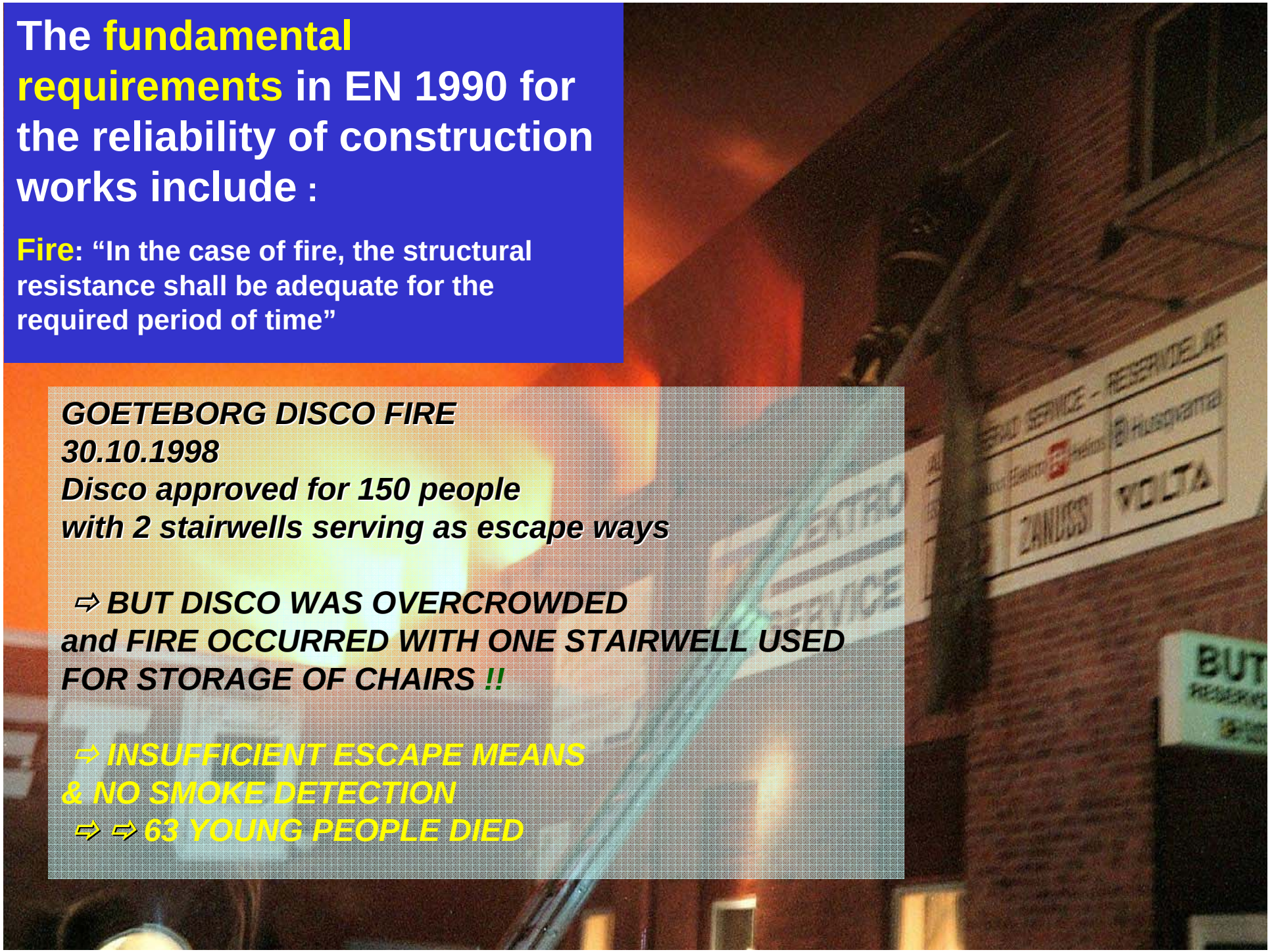
EN 1990 : EUROCODE: BASIS OF STRUCTURAL DESIGN – Bridge Robustness – Vehicle Impact

The fundamental requirements in EN 1990 for the reliability of construction works include :

Fire: "In the case of fire, the structural resistance shall be adequate for the required period of time"



GOETEBORG DISCO FIRE
30.10.1998
Disco approved for 150 people
with 2 stairwells serving as escape ways

⇨ BUT DISCO WAS OVERCROWDED
and FIRE OCCURRED WITH ONE STAIRWELL USED FOR STORAGE OF CHAIRS !!

⇨ INSUFFICIENT ESCAPE MEANS
& NO SMOKE DETECTION
⇨ ⇨ 63 YOUNG PEOPLE DIED

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Reliability differentiation

An appropriate degree of reliability for the majority of structures is obtained by design and execution according to Eurocodes 1 to 9, with appropriate quality assurance measures

EN 1990 provides guidance for obtaining different levels of reliability

Requirement: Reliability Differentiation

The choice of the levels of reliability for a particular structure should take account of the relevant factors, including :

- the possible cause and /or mode of attaining a limit state;
- the possible **consequences of failure** in terms of risk to life, injury, potential economical losses;
- **public perception to failure**;
- the expense and procedures necessary to reduce the risk of failure.

EN 1990 : EUROCODE: BASIS OF STRUCTURAL DESIGN: Chapter 2: DEFINITION OF CONSEQUENCES CLASSES

Consequences Class	Description	Examples of buildings and civil engineering works
CC3	High consequence for loss of human life, or economic, social or environmental consequences very great	Grandstands, bridges, public buildings where consequences of failure are high (e.g. a concert hall)
CC2	Medium consequence for loss of human life, economic, social or environmental consequences considerable	Residential and office buildings, public buildings where consequences of failure are medium (e.g. an office building)
CC1	Low consequence for loss of human life, and economic, social or environmental consequences small or negligible	Agricultural buildings where people do not normally enter (e.g. for storage), greenhouses

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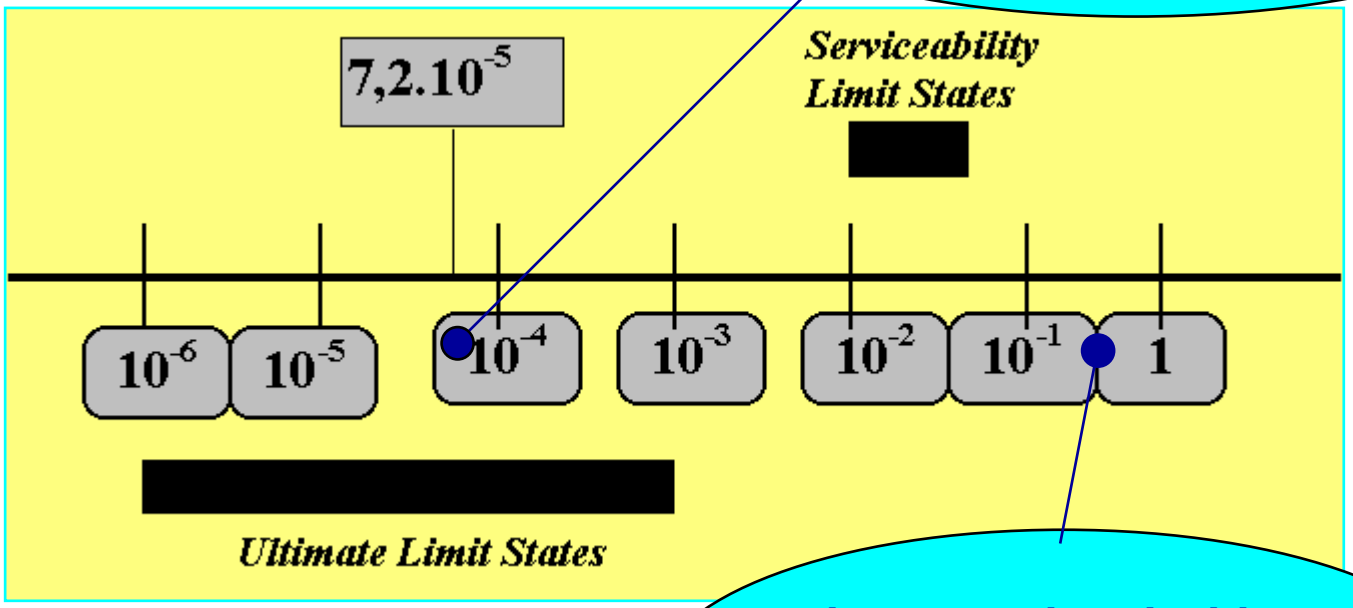
Probabilities Of Failure Associated With Limit States



Value associated with β = 3,8 (ULS, 50 years reference period)

Value associated with β = 1,5 (SLS, 50 years reference Period)

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Accepted risks of death due to exposure to various hazards

Public perception does not accept fatalities and injuries due to structural failure (at home, at the work place, during recreational and other activities etc), for the design working life of a structure compared to fatalities arising from other hazards and events.

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Accepted risks of death due to exposure to various hazards

Hazard	Risk ($\times 10^{-6}$ p.a.)[a]	Hazard	Risk ($\times 10^{-6}$ p.a.)[a]
Building hazards		***Occupations (UK)***	
Structural failure (*UK*)	0,14	Chemical and allied industries	85
Building fires (*Australia*)	4	Ship building and marine engineering	105
		Agriculture	110
		Construction industries	150
		Railways	180
		Coal mining	210
		Quarrying	295
		Mining (non-coal)	750
		Offshore oil and gas *(1967-1976)*	1650
		Deep sea fishing *(1959-1978)*	2800
Natural hazards (U.S)		***Sports (U.S)***	
Hurricanes (1901-1972)	0,4	Cave exploration *(1970-1978)*	45
Tornadoes (1953-1971)	0,4	Glider flying *(1970-1978)*	400
Lightning (1969)	0,5	Scuba diving *(1970-1978)*	420
Earthquakes (California)	2	Hang gliding *(1977-1979)*	1500
		Parachuting *(1978)*	1900
General accidents (U.S 1969)		***All causes (U.K. 1977)***	
Poisoning	20	Whole population	12000
Drowning	30	Woman aged 30	600
Fires and burns	40	Man aged 30	1000
Falls	90	Woman aged 60	10000
Road accidents	300	Man aged 60	20000
[a] risk expressed as probability of death for typical exposed person per calendar year			

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EN 1990: Annex B: Tools for the management of structural reliability

Depending upon the consequences of failure, the main tools selected in EN1990 Annex B for the management of structural reliability of construction works are:

- differentiation by β (reliability index) values; at this stage, this is a specialist activity;
- modification of partial factors;
- design supervision differentiation;
- inspection during execution

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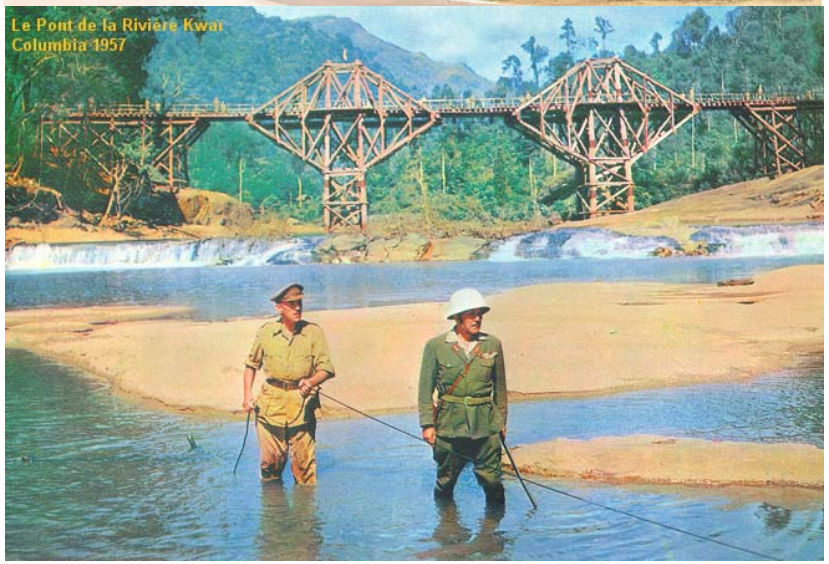
The requirements for design working life states:

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.

a design working life of

- **50 years for buildings**
- **100 years for bridges**

is recommended in EN 1990.



EN 1990 : EUROCODE: BASIS OF STRUCTURAL DESIGN INDICATIVE DESIGN WORKING LIFE

Design working life category	design working Indicative life (years)	Examples
1	10	Temporary structures (1)
2	10 to 25	Replaceable structural parts, e.g. gantry girders, bearings
3	15 to 30	Agricultural and similar structures
4	50	Building structures and other common structures, not listed elsewhere in this table
5	100	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		

Notion of design working life useful for

- The selection of design actions
- (e.g. wind, earthquake)
- Consideration of material property deterioration
- (e.g. fatigue, creep)
- Life cycle costing
- Evolve maintenance strategies

THE REQUIREMENTS

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Durability

It is an assumption in design that the durability of a structure or part of it in its environment is such that it remains fit for use during the design working life given appropriate maintenance

The structure should be designed in such a way that deterioration should not impair the durability and performance of the structure having due regard to the anticipated level of maintenance

Durability

Interrelated factors to be considered:

- 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 structural system

Durability
Interrelated factors to be considered (cont)

- The shape of members and structural detailing
- The quality of workmanship and level of control
- The particular protective measures
- The maintenance during the intended life

THE REQUIREMENTS

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EN 1990 : EUROCODE: BASIS OF STRUCTURAL DESIGN - Quality Assurance and Quality Control

In order to provide a structure that corresponds to the requirements and to the assumptions made in the design, appropriate quality management measures should be in place. These measures comprise:

- definition of the reliability requirements,
- organisational measures, and
- controls at the stages of design, execution, use and maintenance.

EN ISO 9001:2000 is an acceptable basis for quality management measures, where relevant.

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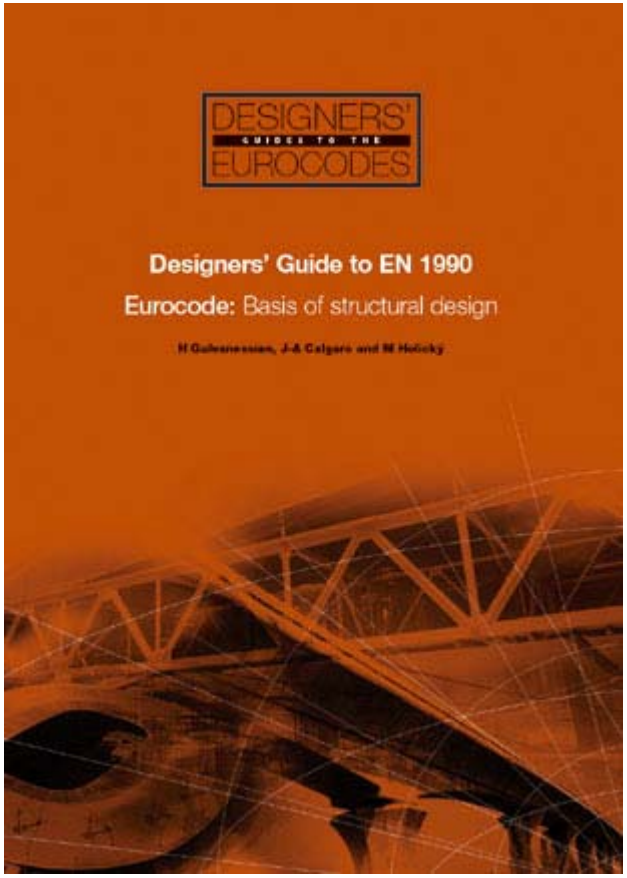
EN 1990: Selected Background Documents and further reading



1) ISO 2394: *General principles on reliability for structures*
2) CEN/TC250 PT for ENV 1991-1: Basis of Design; *Background Document EC1:Part1: Basis of Design*. ECCS 1996.
3) Gulvanessian H, Calgaro J-A, Holicky M: *Designers' Guide to EN 1990: Eurocode: Basis of Structural Design.* Thomas Telford, 2002.
4) 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.
5) Gulvanessian, H., Holický, M: Eurocodes: *Using reliability analysis to combine action effects*, Proceedings of the Institution of Civil Engineers, Structures and Buildings, Thomas Telford. August 2005.
6) CEB Bulletin 203/204/205 CEB-FIP Model Code 90, CEB 1991.
7) Leonardo da Vinci Project CZ/02/B/F/PP-134007: *Implementation of Eurocodes: Handbook 1: Basis of Structural Design*

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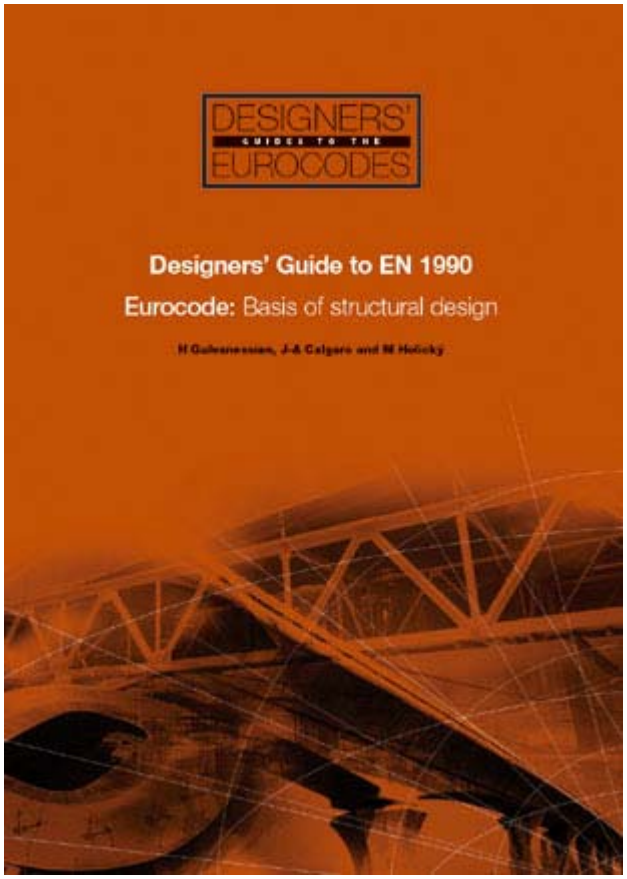

Thank you for your attention

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