Eurocodes and National Annexes

(including EN 1990 and EN 1991)

Barry Haseltine MBE

SHORT INTRODUCTION TO EN 1990 AND EN 1991

Shortened version of presentations given to Workshop in February 2008 (excluding bridges)

***Grateful thanks* to**
Haig Gulvanessian CBE
For some of the slides that are used for this presentation

The full list of Eurocode subjects, with the number of Parts in each is:

EN1990	Basis of Structural Design	1 Part
EN1991	Actions on Structures	10 Parts
EN1992	Design of Concrete Structures	4 Parts
EN1993	Design of Steel Structures	20 Parts
EN1994	Design of Composite Structures	3 Parts
EN1995	Design of Timber Structures	3 Parts
EN1996	Design of Masonry Structures	4 Parts
EN1997	Geotechnical Design	2 Parts
EN1998	Design of Structures for Earthquake Resistance	6 Parts
EN1999	Design of Aluminium Structures	5 Parts

Parts of EC 6

EN 1996: Design of masonry structures has four parts:

EN 1996-1-1: Design of masonry structures – Part 1-1: Common rules for reinforced and unreinforced masonry design

EN 1996-1-2: Design of masonry structures – Part 1-2: General rules – Structural fire design

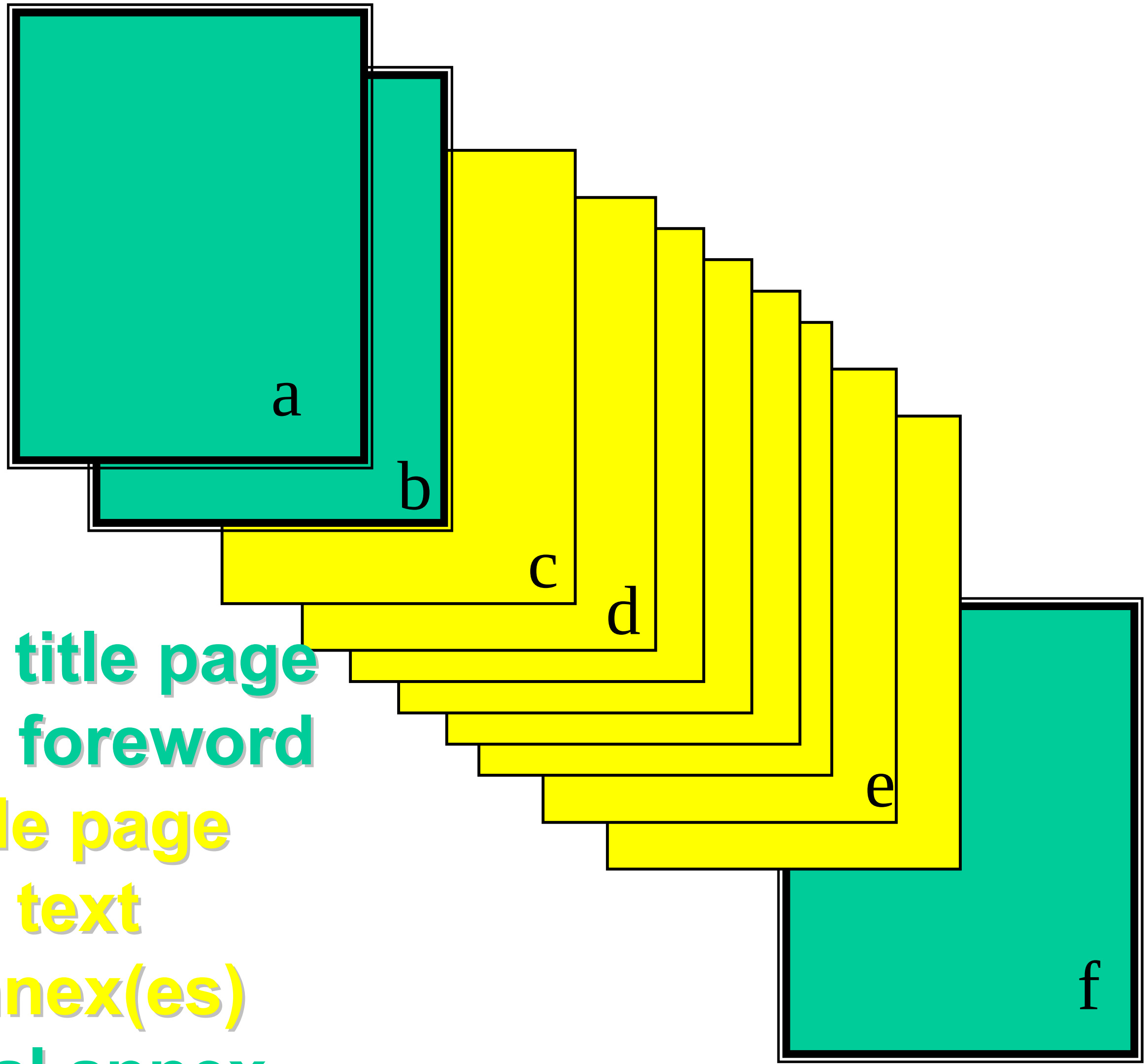
EN 1996-2: Design of masonry structures – Part 2: Design considerations, selection of materials and execution of masonry structures

EN 1996-3: Design of masonry structures – Part 3: Simplified calculation methods for unreinforced masonry structures

Publication of a Eurocode Part and withdrawal of National Codes

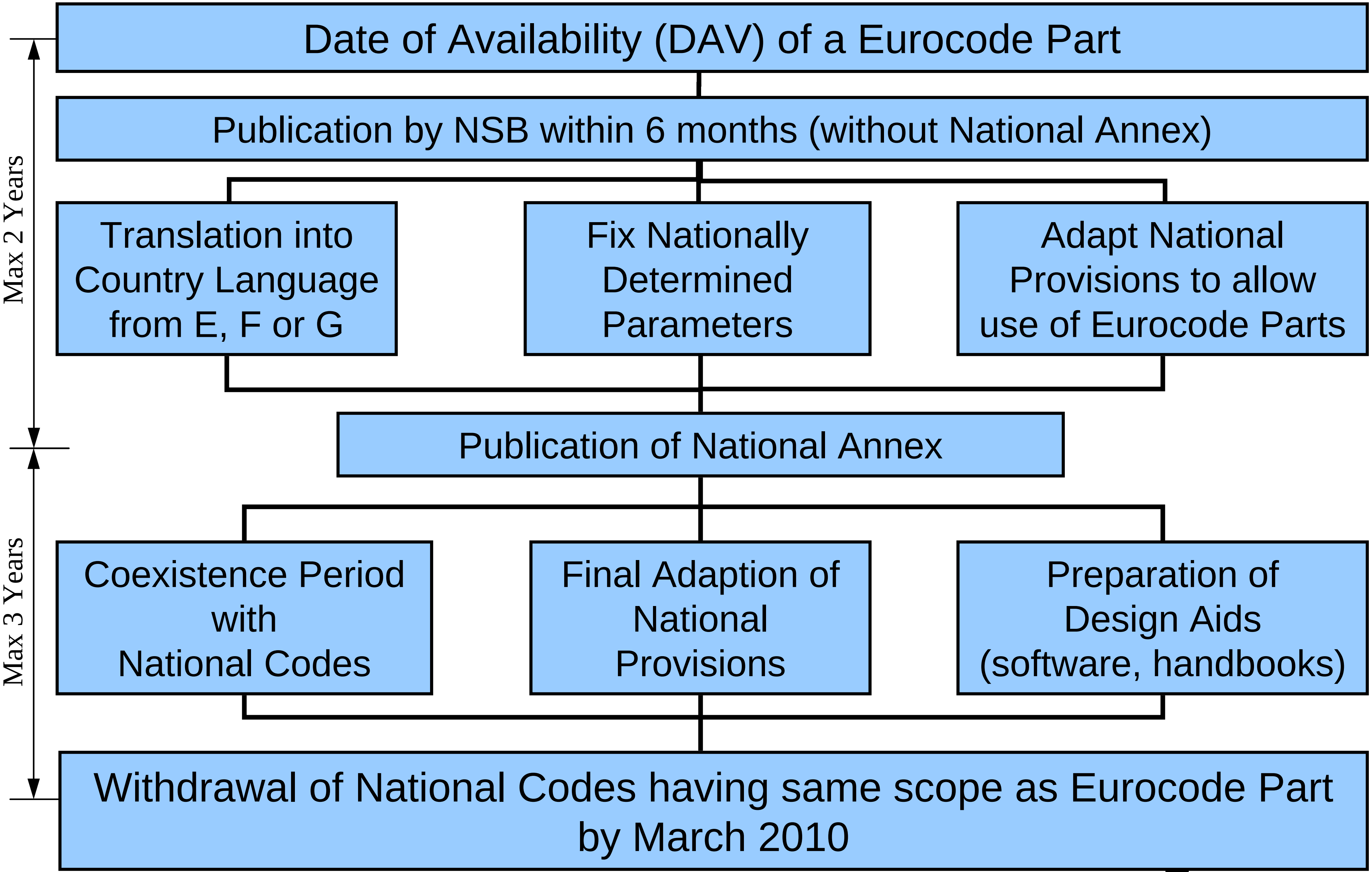
NSB must publish EN Part, from EN title page to the last page of the Annexes (whether Informative or Normative) without any change whatsoever

Elements of a European Standard



a National title page
b National foreword
c EN title page
d EN text
e EN Annex(es)
f National annex

Publication of a Eurocode Part and withdrawal of National Codes



Member States Set Safety Levels

e.g Partial Safety Factors γ

Eurocode Parts allow for National Choice by use of

Classes

Symbols instead of values

Alternative Methods

Country specific data

The National Choice of

a Class

value for a Symbol

method where a choice is given

Country specific data

equals

Nationally Determined Parameter (NDP)

Recommended to give NDPs in National Annexes, published by NSBs *separately* from Parts

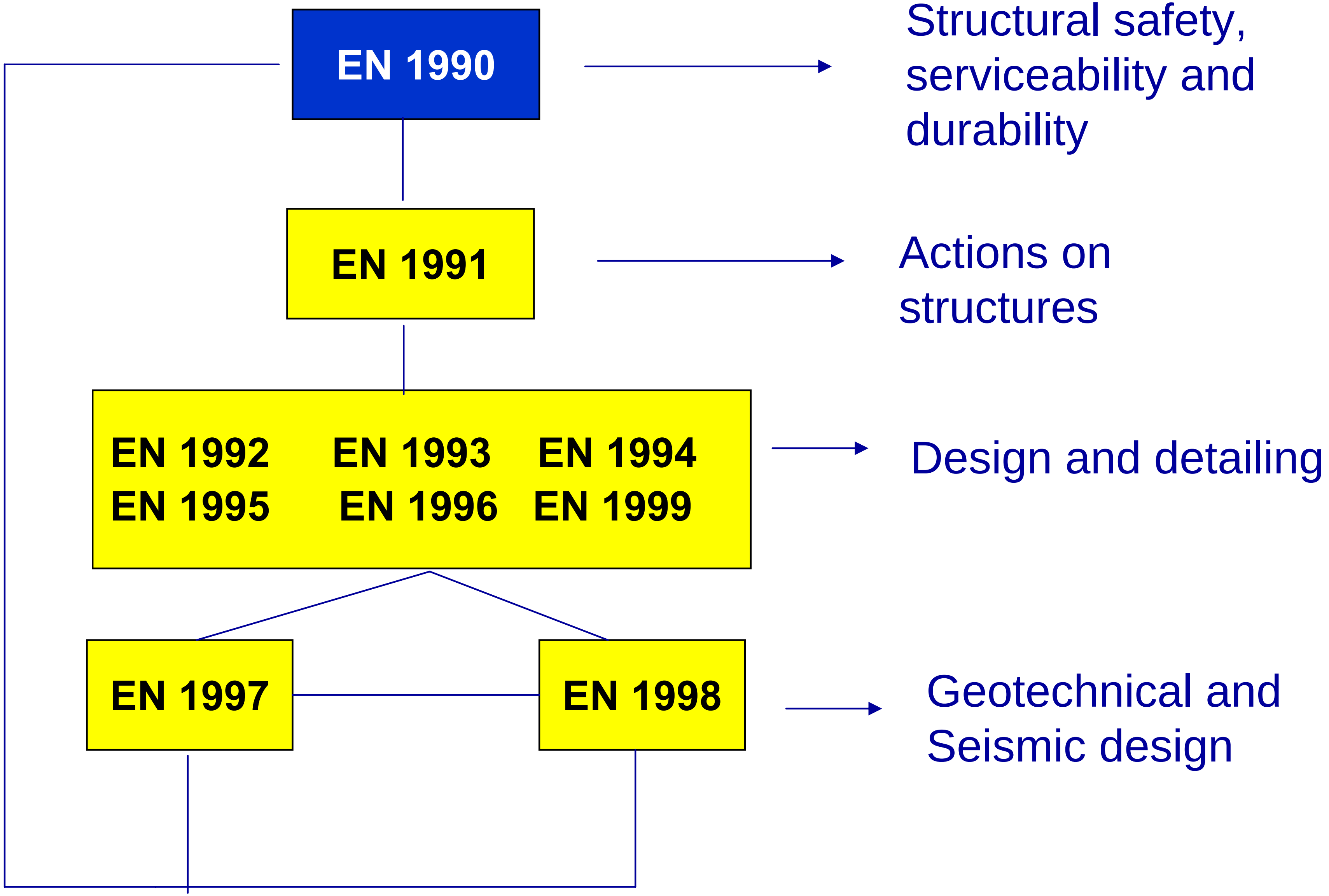
or

Permitted for NDPs to be put in Regulations
or
National Standard (separate from Part)

Decisions on the status of Informative Annexes:

The National Annex should state whether an Informative Annex may or may not be used in a Country. If it may not, then no alternative can be given in the National Annex, but reference can be made to another document for example NCCI

LINKS BETWEEN THE EUROCODES



EN 1990: EUROCODE: BASIS OF STRUCTURAL DESIGN

EN 1990 is the key Eurocode for the design of buildings and civil engineering works

Every Eurocode part from
EN 1991:Eurocode 1: Actions on Structures through the design Eurocodes EN 1992 to EN 1999

requires the use of EN 1990

- EN 1990 provides the material independent and safety related information required for the design of buildings, and civil engineering works for the Eurocodes suite.

EN 1990 : EUROCODE: BASIS OF STRUCTURAL DESIGN: CONTENTS

EN 1990: EUROCODE BASIS OF STRUCTURAL DESIGN

Objectives of EN 1990: Basis of Design

EN 1990 establishes principles and requirements for the

- **Safety**
- **Serviceability**
- **Durability**

of structures; and describes

- **The basis for their design and verification, and**
- **Gives guidelines for related aspects of structural reliability**

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

(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.)

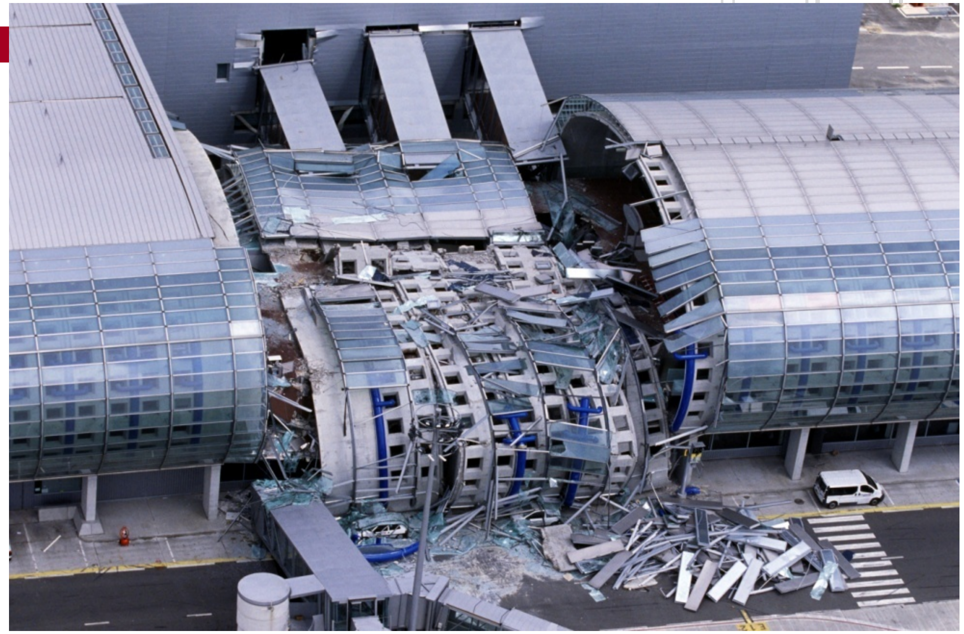
- the construction materials and products are used as specified in EN 1990 or in EN 1991 to EN 1999 or in the relevant execution standards, or reference material or product specifications;
- the structure will be adequately maintained;
- the structure will be used in accordance with the design assumptions.

EN 1990 : EUROCODE: BASIS OF STRUCTURAL DESIGN

THE REQUIREMENTS IN EN 1990

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

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

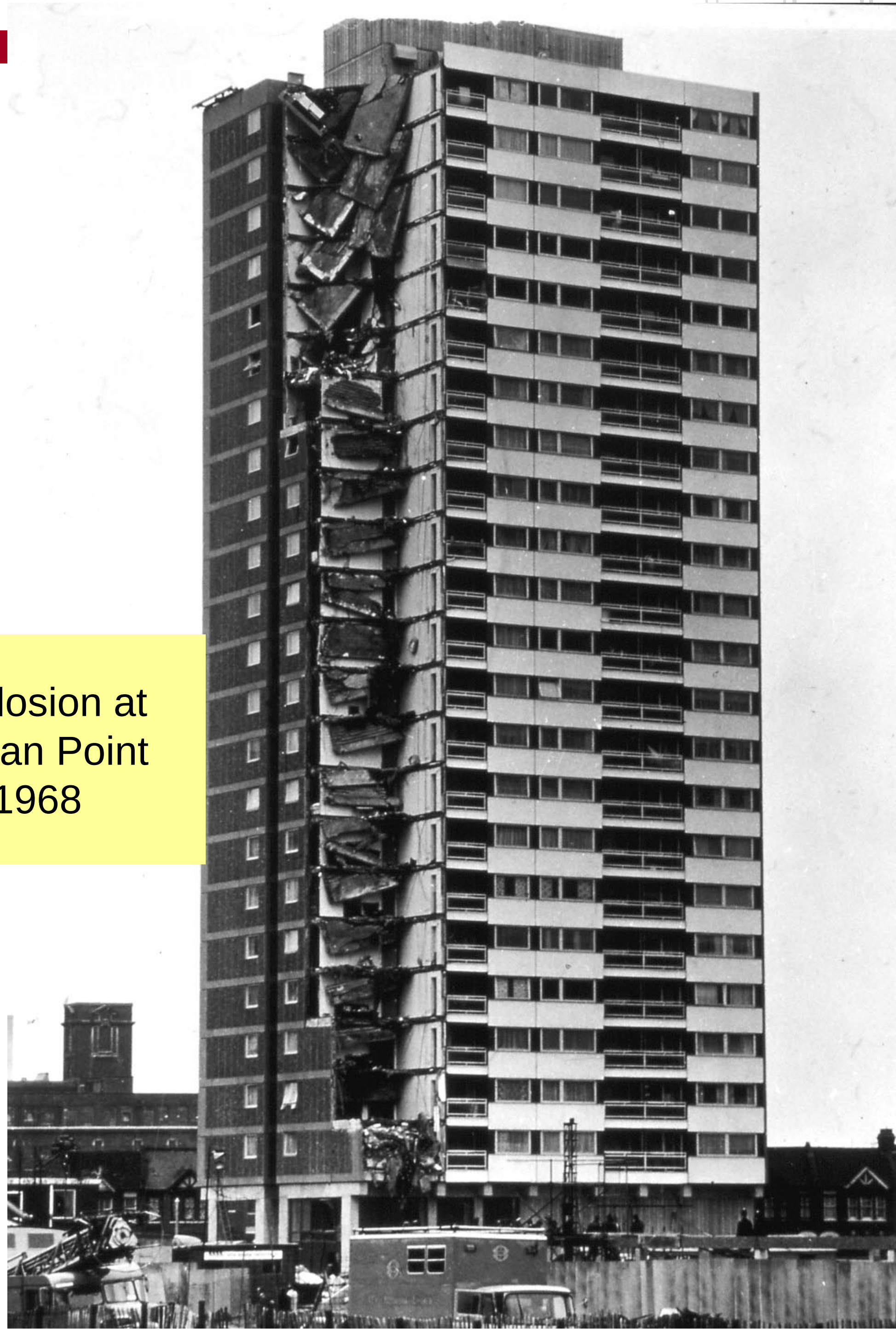
The fundamental requirements in EN 1990 for the reliability of construction works include :

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

EN 1990 : EUROCODE: BASIS OF STRUCTURAL DESIGN

THE REQUIREMENTS IN EN 1990

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

EN 1990: EUROCODE: BASIS OF STRUCTURAL DESIGN

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 of failure;**
- **the expense and procedures necessary to reduce the risk of failure.**

EN 1990: DEFINITION OF CONSEQUENCE CLASSES

Consequence 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

EN 1990: TOOLS FOR THE MANAGEMENT OF STRUCTURAL RELIABILITY

Depending upon the consequences of failure, the main tools selected in EN1990 Annex B (Informative) 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**

EN 1990 : EUROCODE: BASIS OF STRUCTURAL DESIGN

THE REQUIREMENTS IN EN 1990

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

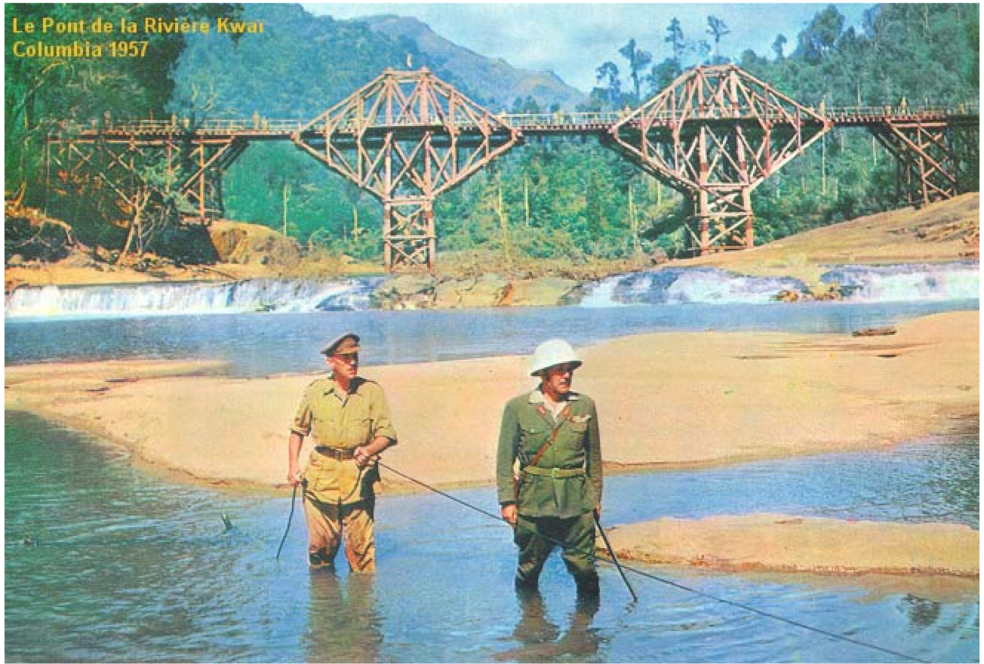
The requirement for design working life states :

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 and**

is recommended in EN 1990.



EN 1990 – 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		

EN 1990 : EUROCODE: BASIS OF STRUCTURAL DESIGN

THE REQUIREMENTS IN EN 1990

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

ULTIMATE LIMIT-STATE :

- the safety of the structure
- the safety of people
- In special circumstances the protection of the contents

- loss of equilibrium of the structure or any part of it, considered as a rigid body
- failure by excessive deformation, transformation of the structure or any part of it into a mechanism, rupture, loss of stability of the structure or any part of it, including supports and foundations
- failure caused by fatigue or other time-dependent effects

SERVICEABILITY LIMIT-STATE

- Functioning of the structure or structural members under normal use,
- comfort of people
- appearance of construction works

EN 1990: EUROCODE: BASIS OF STRUCTURAL DESIGN

Design Situations

Design situations are classified in EN 1990 as follows:

- **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**
- **transient design situations which refer to temporary conditions applicable to the structure, e.g. during execution or repair**

EN1990 : EUROCODE: BASIS OF STRUCTURAL DESIGN

Verifications of static equilibrium and resistance

Individual verifications are performed

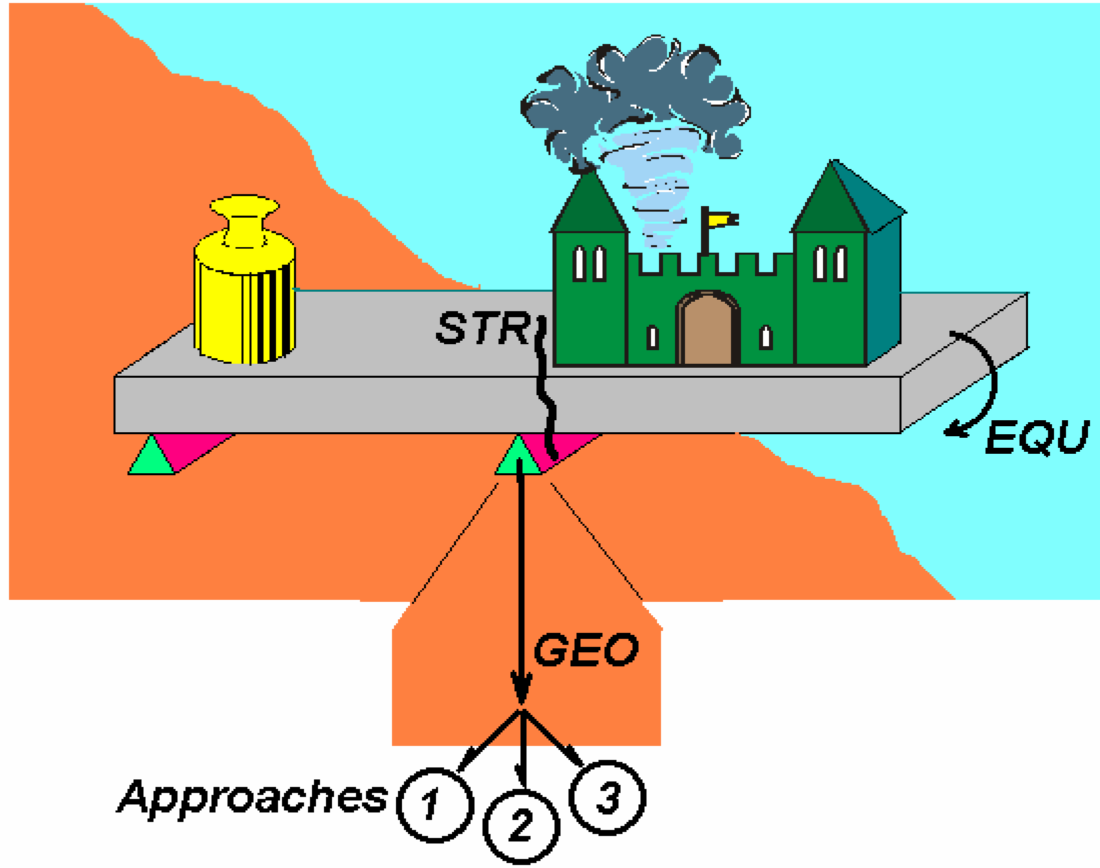
Ultimate limit states of static equilibrium (EQU):

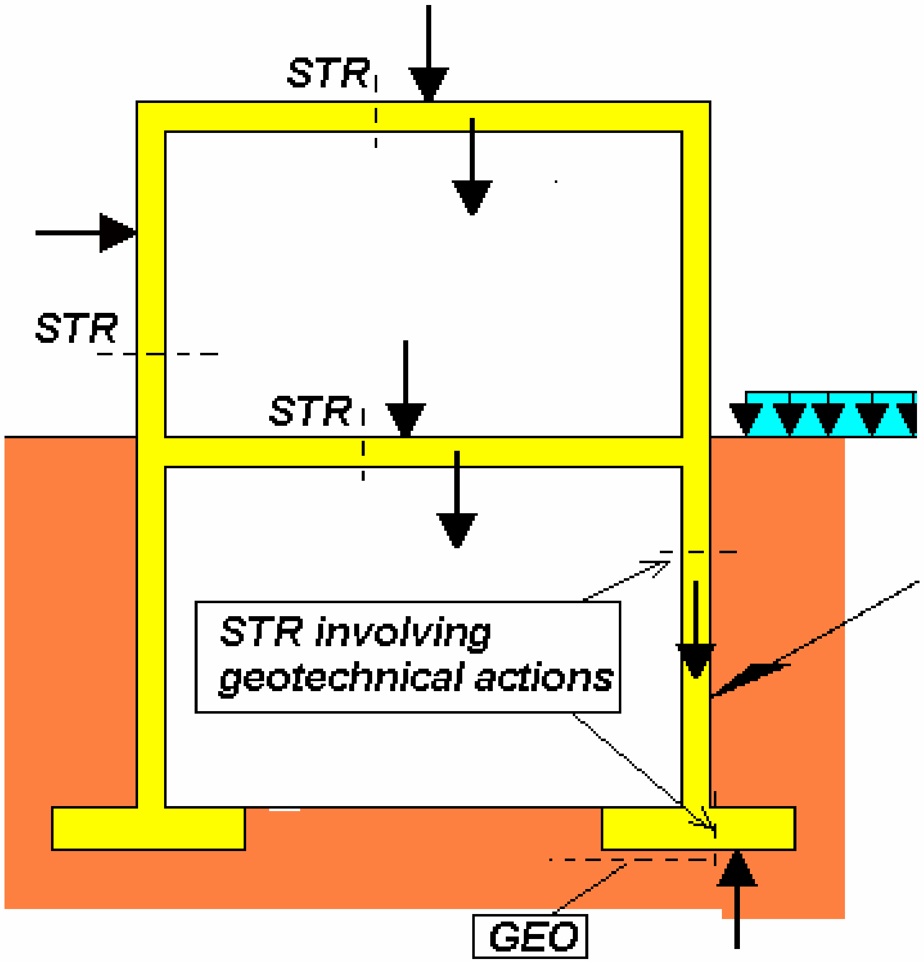
$$E_{d,dst} \leq E_{d,stb}$$

Ultimate limit states of resistance (STR/GEO):

$$E_d \leq R_d$$

EN1990 : EUROCODE: BASIS OF STRUCTURAL DESIGN





Ultimate limit states

EN1990 : EUROCODE: BASIS OF STRUCTURAL DESIGN

Ultimate limit states of STR/GEO - Fundamental combination for persistent and transient design situations

Expression (6.10)

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

Expressions (6.10a) and (6.10b)

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

$$0{,}85 \leq \xi \leq 1{,}00$$

EN 1990 - ULS Verification (Persistent and Transient Design Situation)

$$E_d \leq R_d$$

Applying Equation 6.10 from EN1990:

$$E_d = E \{ \Sigma_{j\geq 1}\gamma_{G,j}G_{k,j} \text{ "+" } \gamma_p P \text{ "+" } \gamma_{Q,1}Q_{k,1} \text{ "+" } \Sigma_{i>1}\gamma_{Q,i}\, \psi_{0,i}\, Q_{k,i} \}$$

EN 1990 - ULS Verification (Persistent and Transient Design Situation)

Design effect

$$E_d = E \{ \Sigma_{j\geq 1}\gamma_{G,j}G_{k,j} \text{"+"} \gamma_p P \text{"+"} \gamma_{Q,1}Q_{k,1} \text{"+"} \Sigma_{i>1}\gamma_{Q,i}\,\psi_{0,i}\,Q_{k,i} \}$$

EN 1990 - ULS Verification (Persistent and Transient Design Situation)

Design effect

$$E_d = E\{ \Sigma_{j\geq 1}\gamma_{G,j}G_{k,j} \text{ "+" } \gamma_p P \text{ "+" } \gamma_{Q,1}Q_{k,1} \text{ "+" } \Sigma_{i>1}\gamma_{Q,i}\,\psi_{0,i}\,Q_{k,i} \}$$

Effect of

EN 1990 - ULS Verification (Persistent and Transient Design Situation)

Design effect

Permanent actions

$$E_d = E\{\Sigma_{j\geq 1}\gamma_{G,j}G_{k,j} \text{“+”} \gamma_p P \text{“+”} \gamma_{Q,1}Q_{k,1} \text{“+”} \Sigma_{i>1}\gamma_{Q,i}\,\psi_{0,i}\,Q_{k,i}\}$$

Effect of

EN 1990 - ULS Verification (Persistent and Transient Design Situation)

Design effect

Permanent actions

$$E_d = E\{\sum_{j\geq 1}\gamma_{G,j}G_{k,j} \text{ "+" } \gamma_p P \text{ "+" } \gamma_{Q,1}Q_{k,1} \text{ "+" } \sum_{i>1}\gamma_{Q,i}\,\psi_{0,i}\,Q_{k,i}\}$$

Effect of

Combined with

EN 1990 - ULS Verification (Persistent and Transient Design Situation)

Design effect

Permanent actions

$$E_d = E\{ \Sigma_{j\geq1}\gamma_{G,j}G_{k,j} \text{“}+\text{”} \gamma_p P \text{“}+\text{”} \gamma_{Q,1}Q_{k,1} \text{“}+\text{”} \Sigma_{i>1}\gamma_{Q,i}\,\psi_{0,i}\,Q_{k,i} \}$$

Effect of

Prestress

Combined with

EN 1990 - ULS Verification (Persistent and Transient Design Situation)

Design effect **Permanent actions** **Leading variable action**

$$E_d = E\{\Sigma_{j\geq 1}\gamma_{G,j}G_{k,j} \text{ “+” } \gamma_p P \text{ “+” } \gamma_{Q,1}Q_{k,1} \text{ “+” } \Sigma_{i>1}\gamma_{Q,i}\,\psi_{0,i}\,Q_{k,i}\}$$

Effect of **Prestress**

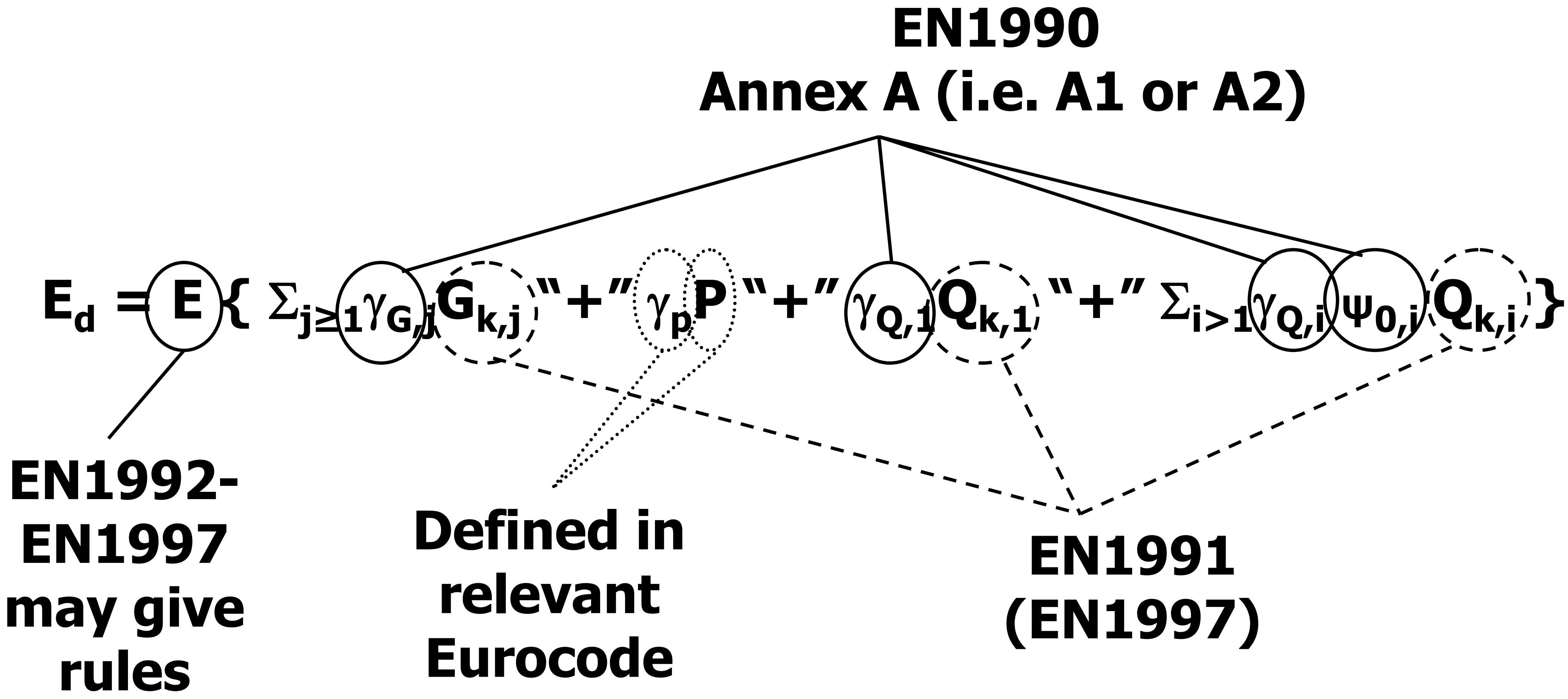
Combined with

EN 1990 - ULS Verification (Persistent and Transient Design Situation)

$$E_d = E\{\Sigma_{j\geq 1}\gamma_{G,j}G_{k,j} \text{“+”} \gamma_p P \text{“+”} \gamma_{Q,1}Q_{k,1} \text{“+”} \Sigma_{i>1}\gamma_{Q,i}\,\psi_{0,i}\,Q_{k,i}\}$$

- E_d: **Design effect**
- E: **Effect of**
- $\Sigma_{j\geq 1}\gamma_{G,j}G_{k,j}$: **Permanent actions**
- “+”: **Combined with**
- $\gamma_p P$: **Prestress**
- $\gamma_{Q,1}Q_{k,1}$: **Leading variable action**
- $\Sigma_{i>1}\gamma_{Q,i}\,\psi_{0,i}\,Q_{k,i}$: **Accompanying variable actions**

EN 1990 - ULS Verification - Where do parameters come from



Annex A –Normative- of EN 1990
gives the partial factors and psi factors for use in buildings and bridges
Annex A1 Buildings and
A2 Bridges (introduced by amendment no 1)

Of course **such vital information as the partial factors for loads appears in the form of symbols, with recommended values.**
Each Country has to choose these factors as NDPs.

EN1990 - EUROCODE : BASIS OF STRUCTURAL DESIGN

Accidental design situations : expression 6.11b

$$\sum_{j\geq 1} G_{k,j} "+" P "+" A_d "+" (\psi_{1,1} \; or \; \psi_{2,1}) Q_{k,1} "+" \sum_{i>1} \psi_{2,i} Q_{k,i}$$

Seismic design situations : expression 6.12b

$$\sum_{j\geq 1} G_{k,j} "+" P "+" A_{Ed} "+" \sum_{i>1} \psi_{2,i} Q_{k,i}$$

EN1990 : EUROCODE: BASIS OF STRUCTURAL DESIGN

Serviceability limit states

It shall be verified that :

$$E_d \leq C_d \qquad (6.13)$$

where :

C_d is the limiting design value of the relevant serviceability criterion

E_d is the design value of the effects of actions specified in the serviceability criterion, determined on the basis of the relevant combination

EN1990 : BASIS OF STRUCTURAL DESIGN

Serviceability limit states : combinations of actions

- Characteristic Combination (irreversible SLS)

$$\sum_{j\geq 1} G_{k,j} "+" P "+" Q_{k,1} "+" \sum_{i>1} \psi_{0,i} Q_{k,i}$$

- Frequent Combination (reversible SLS)

$$\sum_{j\geq 1} G_{k,j} "+" P "+" \psi_{1,1} Q_{k,1} "+" \sum_{i>1} \psi_{2,i} Q_{k,i}$$

- Quasi-permanent Combination (reversible SLS)

$$\sum_{j\geq 1} G_{k,j} "+" P "+" \sum_{i\geq 1} \psi_{2,i} Q_{k,i}$$

EUROCODE 1991

Actions

EN 1991 Actions on Structures

Part 1-1 Densities, self-weight and imposed loads
Part 1-2 Actions on structures exposed to fire
Part 1-3 Snow Loads
Part 1-4 Wind actions
Part 1-5 Thermal actions
Part 1-6 Actions during execution
Part 1-7 Accidental actions
Part 2 Traffic loads on bridges
Part 3 Actions induced by cranes and machinery
Part 4 Actions in silos and tanks

EN 1991 Actions on Structures

Part 1-1 Densities, self-weight and imposed loads

Part 1-2 Actions on structures exposed to fire

Part 1-3 Snow Loads

Part 1-4 Wind actions

Part 1-5 Thermal actions

Part 1-6 Actions during execution

Part 1-7 Accidental actions

Part 2 Traffic loads on bridges

Part3 Actions induced by cranes and machinery

Part4 Actions in silos and tanks

EN 1991 Actions on Structures

Part 1-1 Densities, self-weight and imposed loads

Part 1-2 Actions on structures exposed to fire

Part 1-3 Snow Loads

Part 1-4 Wind actions

Part 1-5 Thermal actions

Part 1-6 Actions during execution

Part 1-7 Accidental actions

Part 2 Traffic loads on bridges

Part3 Actions induced by cranes and machinery

Part4 Actions in silos and tanks

EUROCODE 1991

Most Parts of the Series of Codes on Actions are frameworks

Almost all values will have to be determined Nationally

EN 1991-1-1: Contents

N.B. imposed loads due to occupancy and maintenance are given only in EN 1991-1-1 (unlike BS6399 Part 3). Snow Loads on roofs are given in BS EN 1991-1-3

Self-weight of construction works:

generally a ***Permanent Fixed*** action,

If ***Free*** (e.g. moveable partitions) then treat as an additional imposed load.

Ballast and earth loads on roofs/terraces: ***Permanent*** with variations in properties (moisture content, depth) during the design life being taken into account.

If ***Variable with time*** then represented by upper and lower characteristic values, and

***Imposed loads on buildings*:**
generally *Variable Fixed or Variable Free* actions

Imposed loads generally *quasi-static* and allow for small dynamic effects in static structures. When dynamic response possible, a dynamic analysis is recommended as per the National Annex

Actions causing significant acceleration of structural members are classified as *dynamic* and need to be considered via a dynamic analysis

For *fork-lift trucks* and *helicopters* additional inertial loads from hoisting and take-off/landing are accounted for through a *dynamic magnification factor* applied to appropriate *static* load values

EN 1991-1-1: Densities of construction and stored materials

Characteristic values **of densities of construction and stored materials should generally be used in the expressions for combination of actions.**

Where *only mean values available*, they should be taken as *characteristic* values in the design. Mean values for a large number of different materials are given in EN 1991-1-1 Annex A.

Self-weight **is generally represented by a** ***single characteristic value*** **calculated from nominal dimensions, characteristic values of densities and including, where appropriate, ancillary elements, e.g. non-structural elements and fixed services, weight of earth and ballast.**

Characteristic values **of loads for floors and roofs for the following types of occupancy and use:**

residential, social, commercial and administration areas

garage and vehicle traffic

areas for storage and industrial activities

roofs

helicopter landing areas

barriers and walls having the function of barriers.

EN 1991-1-1: Imposed loads on buildings

Loads arise due to occupancy and the values given in EN 1991-1-1 account for

normal use by persons

furniture and moveable objects,

vehicles

rare events such as concentrations of people and furniture during times of re-organisation and refurbishment

Floor and roof areas in buildings are sub-divided into 11 *categories* according to use; loads specified are represented by *uniformly distributed loads (UDL), concentrated loads*, *line loads* or combinations thereof.

Heavy equipment such as may be found in communal kitchens or boiler rooms are specifically excluded from EN 1991-1-1. Need to be agreed with the Client and the relevant Authority for specific projects.

Table 6.1 – Categories of use

Category	Specific use	Example
A	Areas for domestic and residential activities	Rooms in residential buildings and houses; bedrooms and wards in hospitals; bedrooms in hotels and hostels kitchens and toilets.
B	Office areas	
C	Areas where people may congregate (with the exception of areas defined under category A, B and D[1)])	**C1**: Areas with tables, etc e.g. areas in schools, cafes, restaurants, dining halls, reading rooms, receptions **C2**: Areas with fixed seats, e.g. areas in churches, theatres or cinemas, conference rooms, lecture halls, assembly halls, waiting rooms, railway waiting rooms. **C3**: Areas without obstacles for moving people, e.g. areas in museums, exhibition rooms, etc. and access areas in public and administration buildings, hotels, hospitals, railway station forecourts **C4**:Areas with possible physical activities, e.g. dance halls, gymnastic rooms, stages . **C5**:Areas susceptible to large crowds, e.g. in buildings for public events like concert halls, sports halls including stands, terraces and access areas and railway platforms.
D	Shopping areas	**D1:** Areas in general retail shops **D2**: Areas in department stores.

[1)] Attention is drawn to 6.3.1.1(2), in particular for C4 and C5. See EN 1990 when dynamic effects need to be considered. For Category E, see Table 6.3

NOTE 1. Depending on their anticipated uses, areas likely to be categorised as C2, C3, C4 may be categorised as C5 by decision of the client and/or National annex.

NOTE 2. The National annex may provide sub categories to A, B, C1 to C5, D1 and D2

NOTE 3. See 6.3.2 for storage or industrial activity

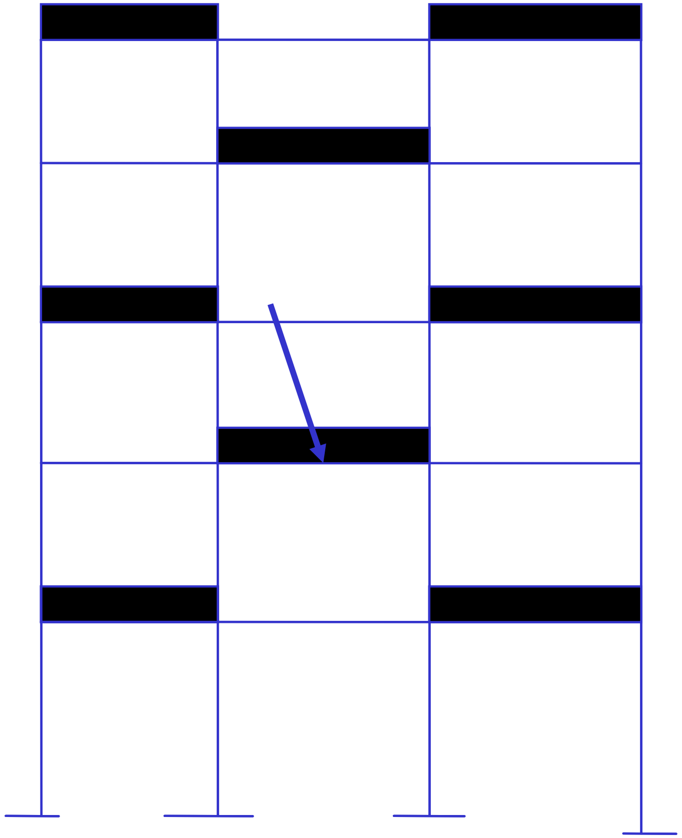
Imposed loads on buildings – Loads for floors etc

Table 6.2 – Imposed loads on floors, balconies and stairs in buildings

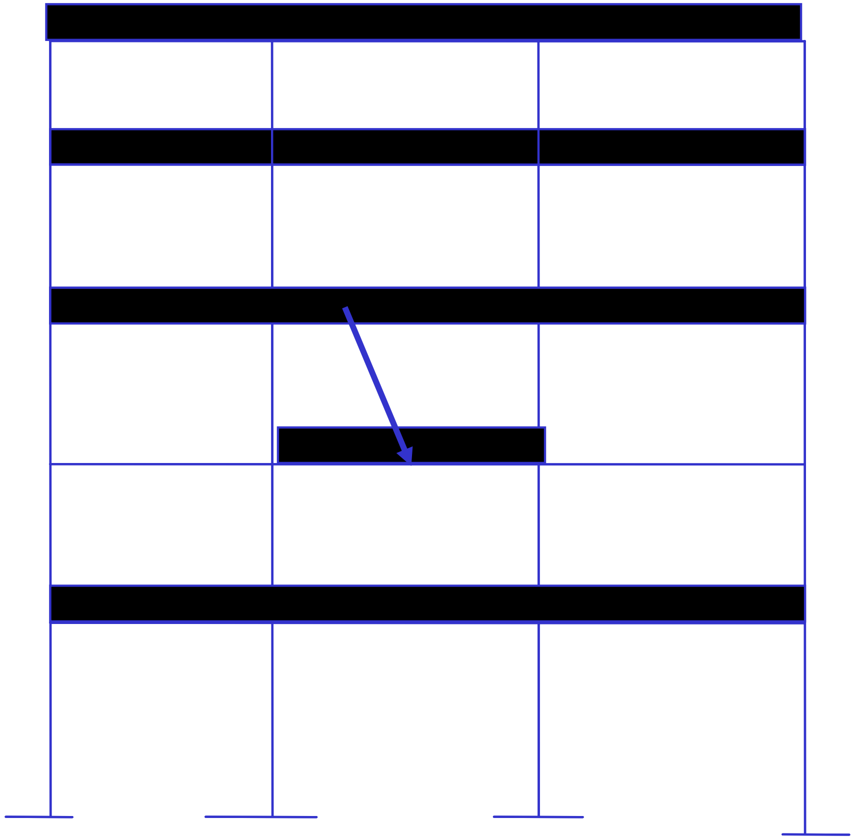
Categories of loaded areas	**q_k [kN/m^2]**	**Q_k [kN]**
Category A		
- Floors	1,5 to 2,0	2,0 to 3,0
- Stairs	2,0 to 4,0	2,0 to 4,0
- Balconies	2,5 to 4,0	2,0 to 3,0
Category B	2,0 to 3,0	1, 5 to 4,5
Category C		
- C1	2,0 to 3,0	3,0 to 4,0
- C2	3,0 to 4,0	2,5 to 7,0 (4,0)
- C3	3,0 to 5,0	4,0 to 7,0
- C4	4,5 to 5,0	3,5 to 7,0
- C5	5,0 to 7,5	3,5 to 4,5
Category D		
-D1	4,0 to 5,0	3,5 to 7,0 (4,0)
-D2	4,0 to 5,0	3,5 to 7,0

NOTE: Where a range is given in this table, the value may be set by the National annex. The recommended values, intended for separate application, are underlined. q_k is intended for the determination of general effects and Q_k for local effects. The National annex may define different conditions of use of this Table.

Mid span bending moment of a floor structure



Chess board arrangement



Simplification in EN 1991-1-1

Main Categories of Use

Residential, social, commercial and administration areas

- **4** ***categories (A, B, C and D)***

Areas for storage and industrial activities

- **2** ***categories (E1 and E2)***

Garages and vehicle traffic (excluding bridges)

- **2** ***categories (F and G)***

Roofs

- **3** ***categories (H, I and K)***

Roofs

Category H **– Accessible for normal maintenance and repair only**

Category I **– Accessible with occupancy according to categories A to G**

Category K **– Accessible for special services e.g. helicopter landing areas**

EN 1991-1-1: ANNEX A: Table A.1 - Construction materials-concrete and mortar

Materials	Density γ [kN/m³]
concrete (see EN 206)	
lightweight	
density class LC 1,0	9,0 to 10,0 [1)2)]
density class LC 1,2	10,0 to 12,0 [1)2)]
density class LC 1,4	12,0 to 14,0 [1)2)]
density class LC 1,6	14,0 to 16,0 [1)2)]
density class LC 1,8	16,0 to 18,0 [1)2)]
density class LC 2,0	18,0 to 20,0 [1)2)]
normal weight	24,0 [1)2)]
heavy weight	> [1)2)]
mortar	
cement mortar	19,0 to 23,0
gypsum mortar	12,0 to 18,0
lime-cement mortar	18,0 to 20,0
lime mortar	12,0 to 18,0

[1)] Increase by 1kN/m³ for normal percentage of reinforcing and pre-stressing steel
[2)] Increase by 1kN/m³ for unhardened concrete

NOTE See Section 4

EN 1991-1-1: ANNEX A: Table A.12 - Stored products - industrial and general

Products	Density γ [kN/m³]	Angle of repose ϕ[°]
books and documents		-
books and documents,	6,0	-
densely stored	8,5	-
filing racks and cabinets	6,0	-
garments and rags, bundled	11,0	-
ice, lumps	8,5	-
leather, piled	10,0	-
paper		
in rolls	15,0	-
piled	11,0	-
rubber	10,0 to 17,0	-
rock salt	22,0	45
salt	12,0	40
sawdust		
dry, bagged	3,0	-
dry, loose	2,5	45
wet, loose	5,0	45
tar, bitumen	14,0	-
NOTE See Section 4.		

EN 1991-1-3 – Field of application

EN 1991-1-3 provides guidance for the determination of the snow load to be used for the structural design of buildings and civil works for sites at altitudes under 1500m.

EN 1991-1-3 – Field of application

EN 1991-1-3 does not give guidance on specialist aspects of snow loading, for example:

“impact snow loads” resulting from snow sliding off or falling from a higher roof;

the additional wind loads which could result from changes in shape or size of the building structure due to the presence of snow or the accretion of ice;

loads in areas where snow is present all the year;

ice loading;

lateral loading due to snow (e.g. lateral loads exerted by drifts).

EN 1991-1-3 - Contents

Characteristic ground snow loads

- Ground snow load map
- Altitude function

Coefficients

- Shape coefficient – Roof shape
- Exposure coefficient – Topography
- Thermal coefficient – Thermal transmittance of roofing material

Characteristic Snow Loads on the Ground

Development of a Ground Snow Load Map for Europe

There were inconsistencies at borders between existing national maps

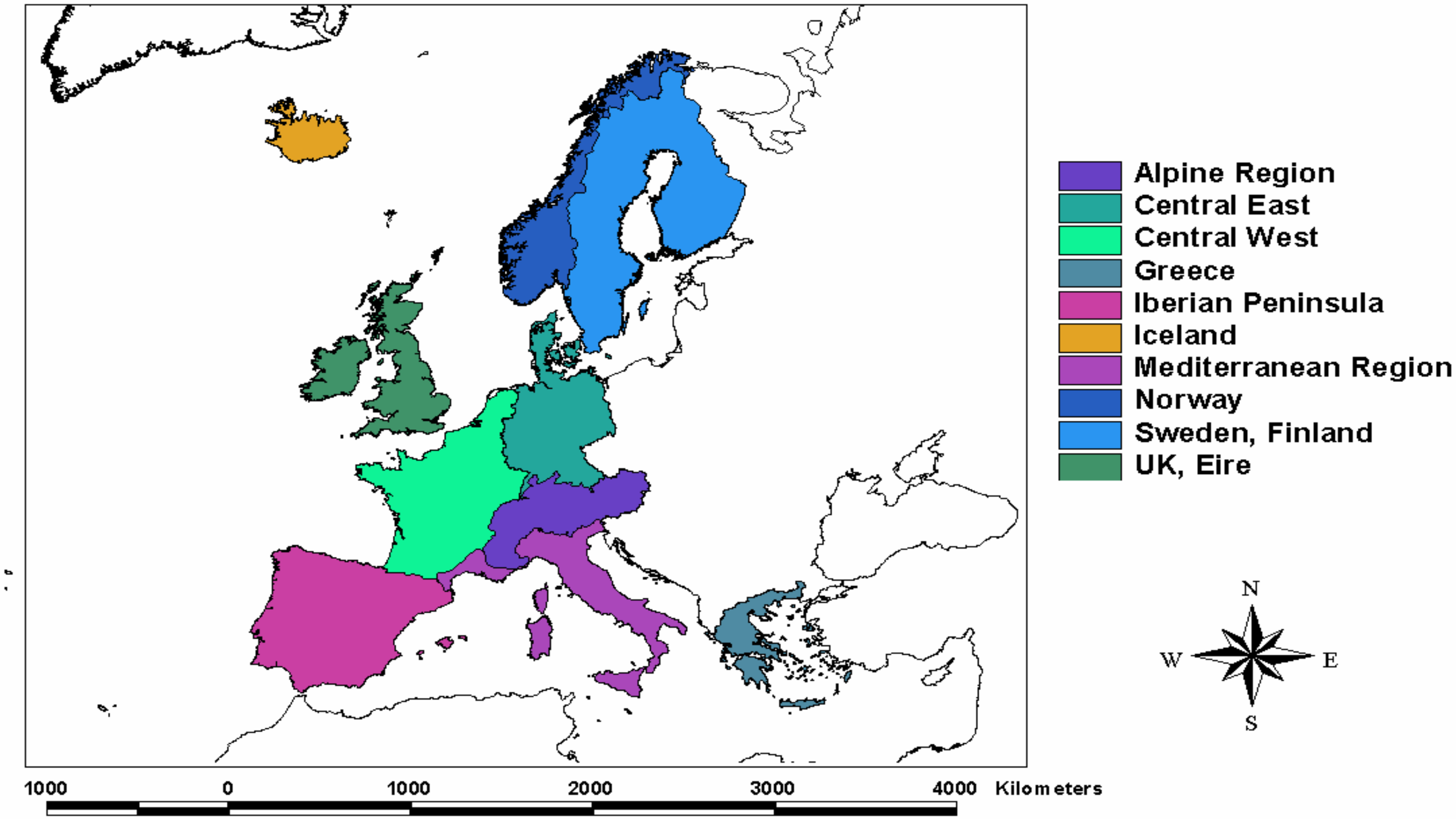
The research developed a consistent approach

Produced regional maps. These are given in Annex C of EN 1991-1-3

- Snow load with Altitude relationship
- Zone numbers & altitude function
- Geographical boundaries

Ground Snow load map European Climatic Regions: Member States presently covered

Climatic Regions



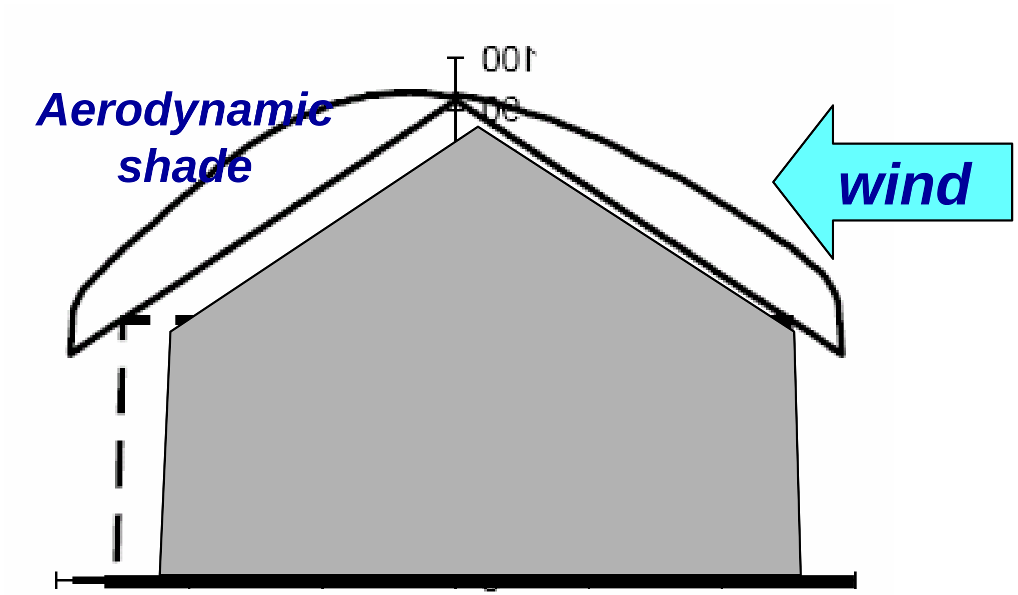
Proposal being prepared to extend map to cover the whole of Europe

UndriftedSnow load on roofs

Drifted Snow on Roof

With wind speeds in the range of 4 to 5 m/s, much of the snow is deposited in areas of *'aerodynamic shade'*

DRIFTED SNOW LOAD ARRANGEMENT



Model in wind tunnel

wind velocity of 4m/s

Background to EN1991-1-4

Wind speed is measured and modelled differently throughout Europe

Different wind climates in Europe?

Major areas of disagreement - National Choice

Impossible to get consensus on all parts of EN1991-1-4

There are 47 clauses or Notes where a recommended procedure is given but where National Choice is allowed, plus six informative annexes

It is expected that Member States will adopt the recommended procedures in most cases, except where issues of safety or economy arise

EN1991-1-4: - Contents List

Description of wind actions (internal pressures, external pressures, forces and friction forces, dynamic response)

Classification of wind action as variable fixed actions

Definition of characteristic values

Section 4: Wind velocity and velocity pressure

Basic wind velocity $v_b = c_{dir}\, c_{season}\, v_{b,0}\, c_{prob}$

where

$v_{b,0}$ = 10 minute mean velocity at 10m above ground (z_0 = 0.05) (tc II)

c_{dir} = directional factor

c_{season} = seasonal factor

c_{prob} = probability factor

National choice allowed

Mean wind velocity $v_m(z) = c_r(z)\, c_o(z)\, v_b$

where $c_r(z)$ = roughness factor $= k_r\, ln(z/z_o)$

k_r = terrain factor depending on z_o

$c_0(z)$ = orography (i.e. topography) factor

Wind Pressure and Pressure Coefficients

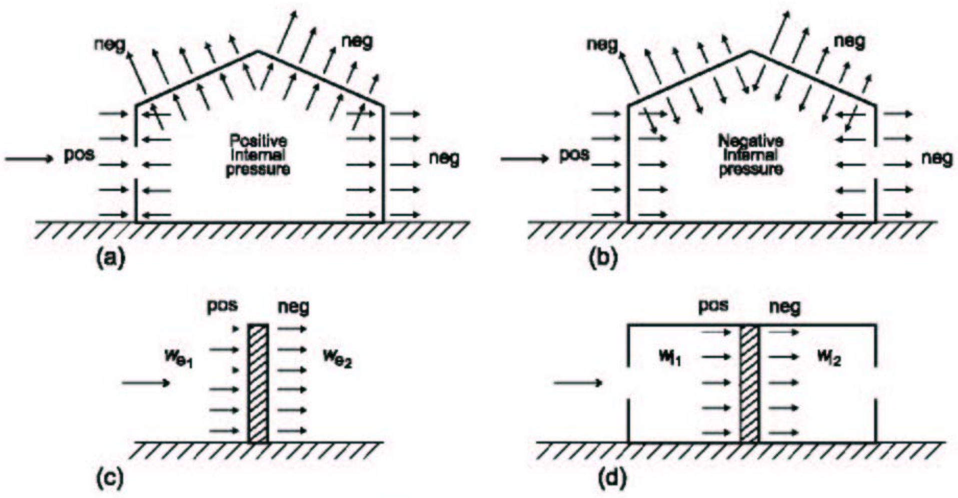


Figure 5.1 — Pressure on surfaces

External wind pressure

$$w_e = c_{pe} \cdot q_p(z_e)$$

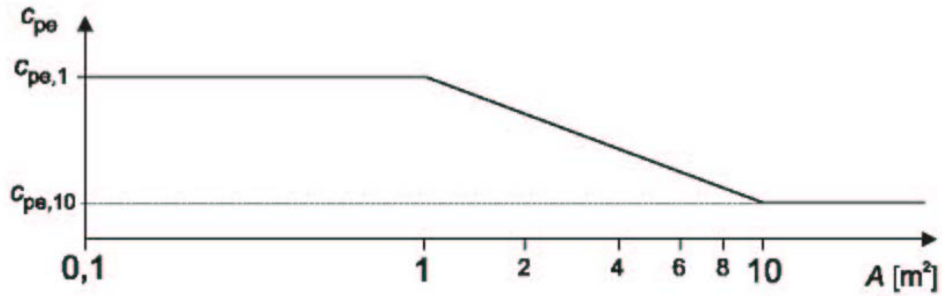
c_{pe} → external pressure coefficient

Internal wind pressure

$$w_i = c_{pi} \cdot q_p(z_i)$$

c_{pi} → internal pressure coefficient

c_{pe} depends on the size of the considered element



The figure is based on the following:

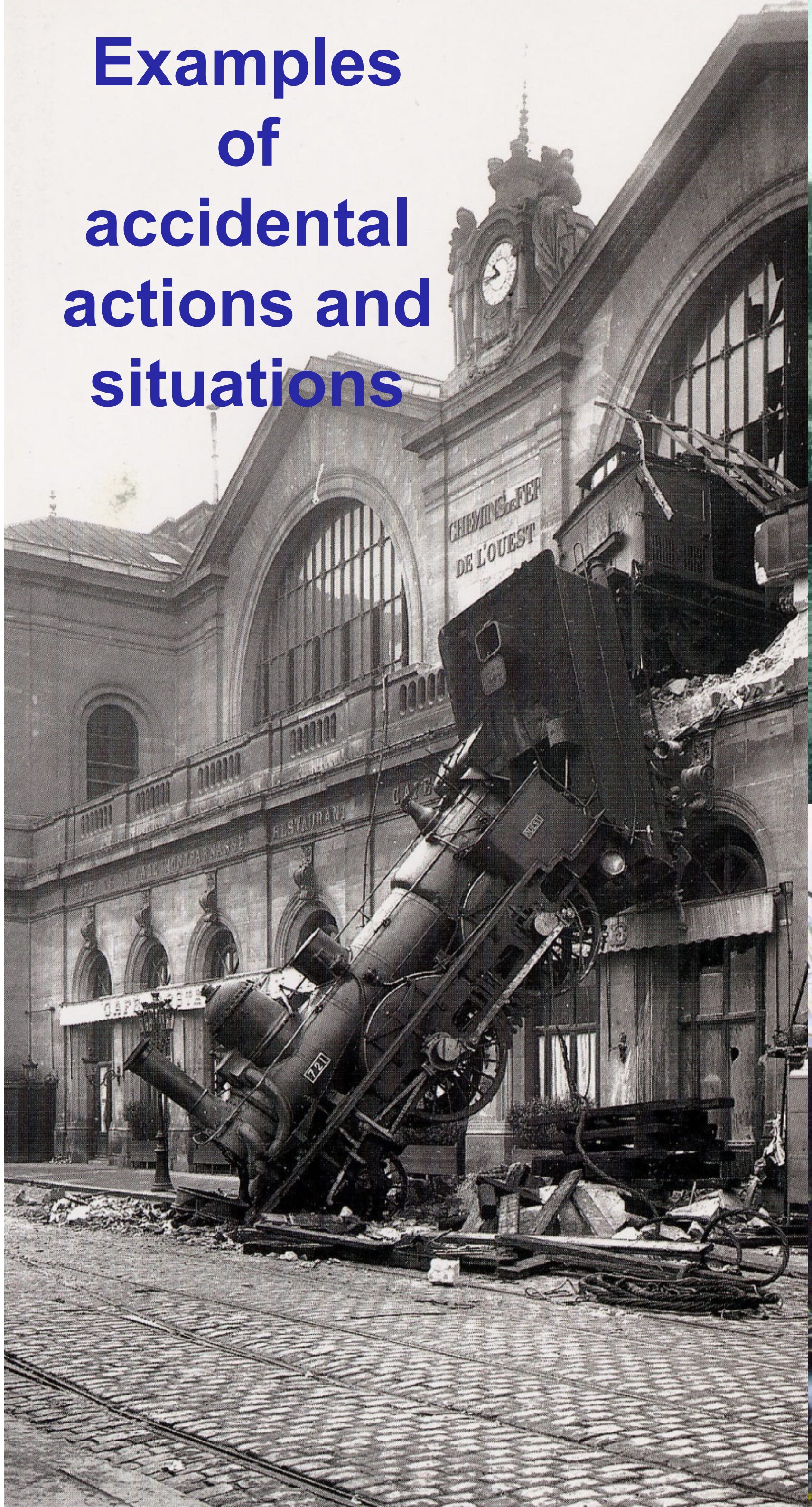
for $A \leq 1$ m² $c_{pe} = c_{pe,1}$
for 1 m² < A < 10 m² $c_{pe} = c_{pe,1} - (c_{pe,1} - c_{pe,10}) \log_{10} A$
for $A \geq 10$ m² $c_{pe} = c_{pe,10}$

$c_{pe,1}$ values only apply to clauses 7.2.2 to 7.2.6

Figure 7.2 — Recommended procedure for determining the external pressure coefficient c_{pe} for buildings with a loaded area A between 1 m² and 10 m²

EN 1991-1-7: Accidental Actions: Contents

Examples of accidental actions and situations



Vehicle Impacts

Potters Marston Experiment

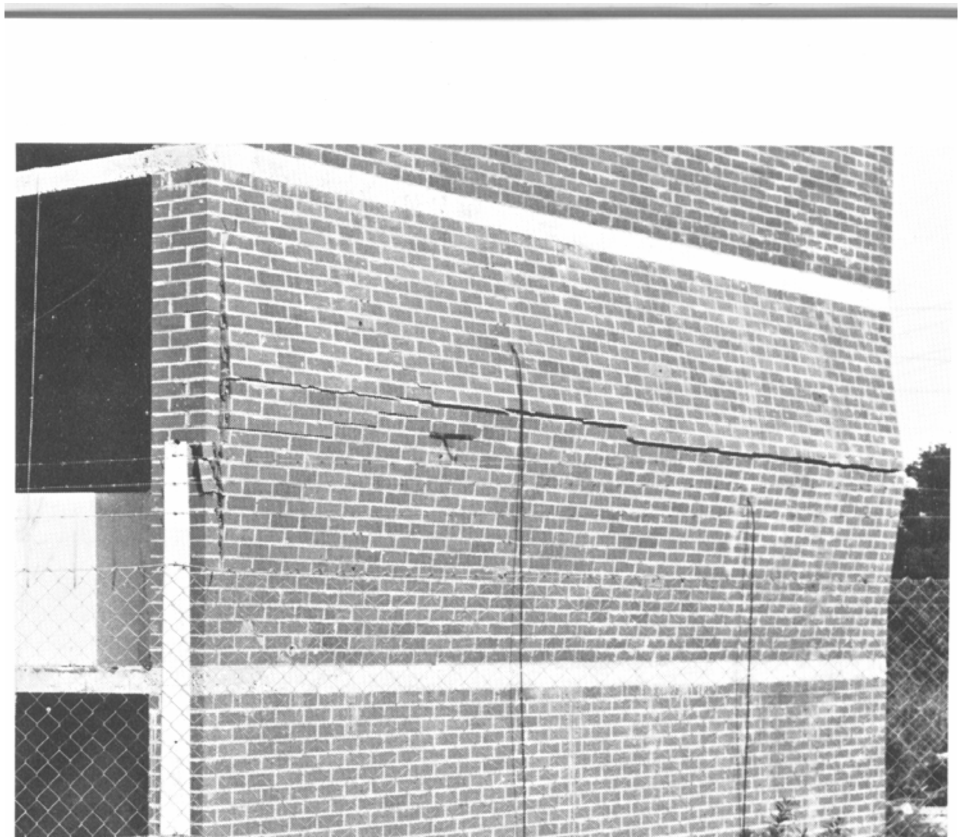
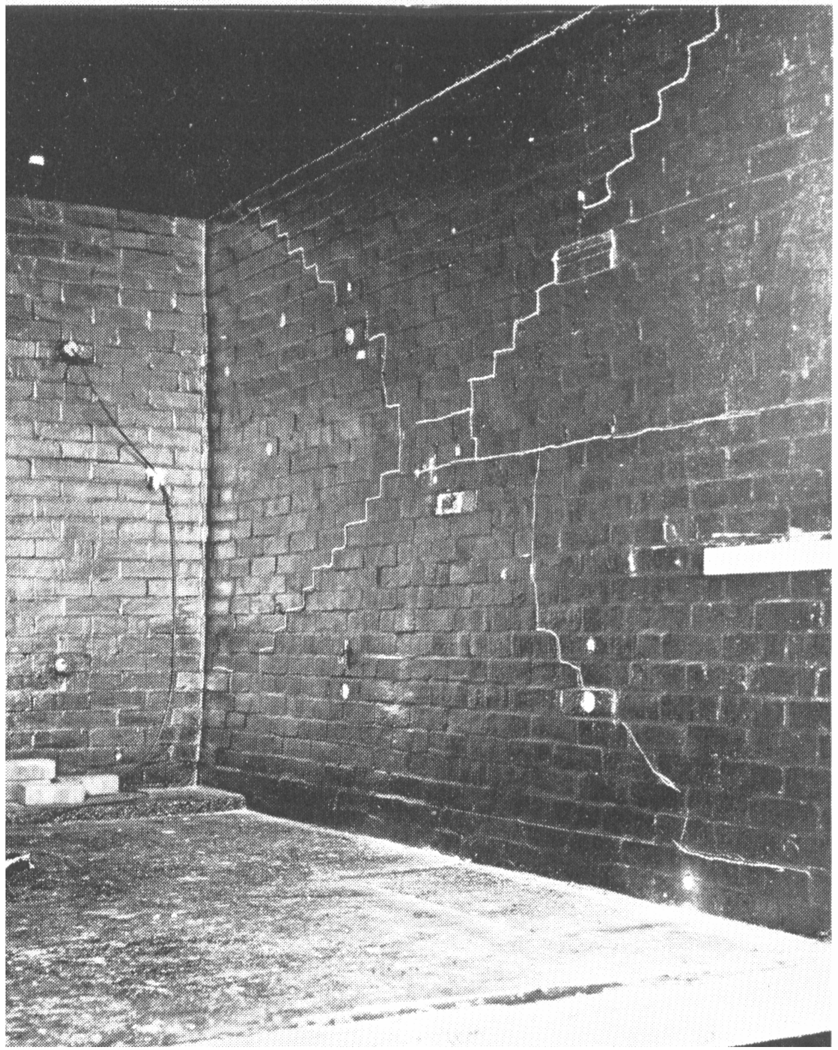
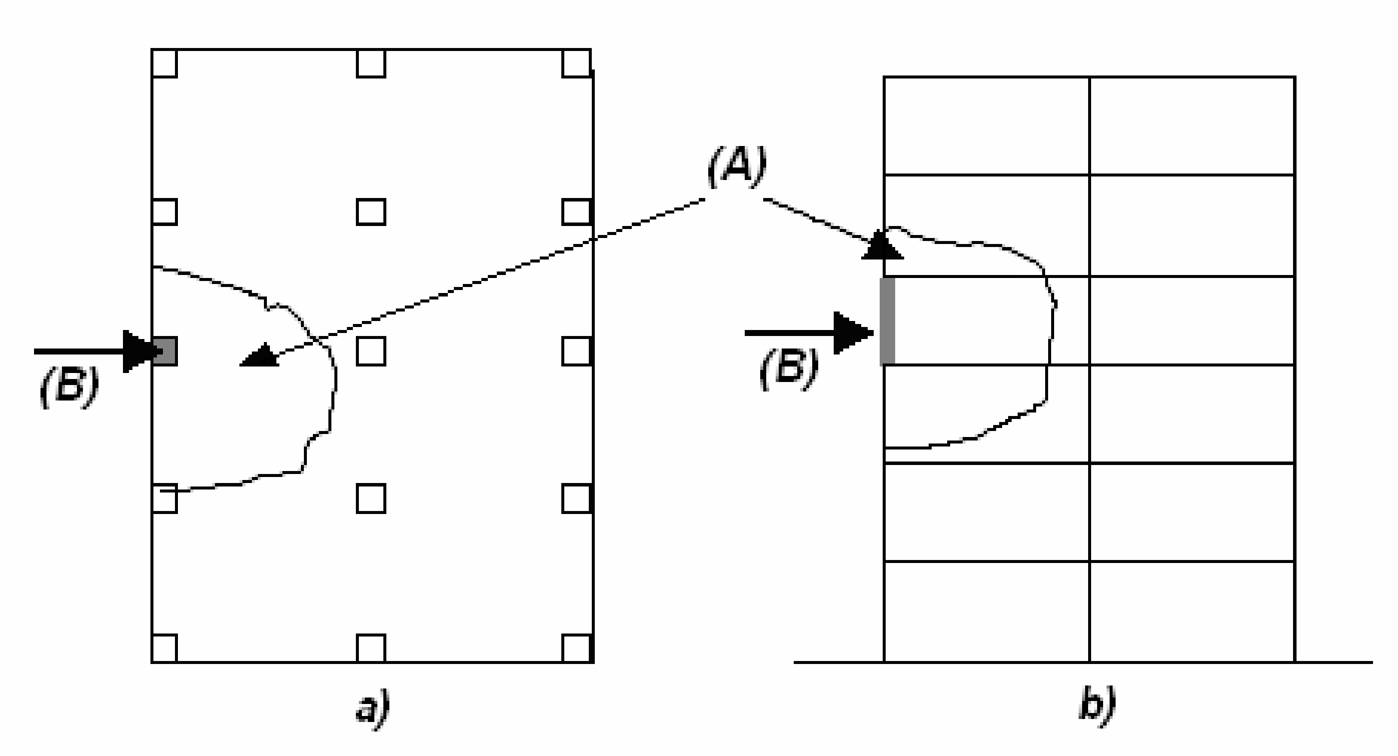


Fig 6. The result of Round 49: yield line cracking of the inner leaf in Room 1.



Recorded pressure 22.7 kN/m²

Limits of admissible damage



(A) is :
- 15% of the floor area or
- 100m² whichever is the smaller, in each of two adjacent storeys

a) is the plan
b) is the elevation

(B) : Notional columns to be removed

Necessarily a very short overview of the Eurocodes

EN 1990

EN 1991 Part -1-1

Part -1-3

Part -1-4

Part -1-7

Hopefully has set the scene for the detailed explanations about EN 1996 itself

Eurocode for Masonry, EN 1996-1-1 and EN 1996-2: Guidance and worked examples

Purchase from IMS

£35.00 for members of IMS

£45.00 for non-members

SPECIAL PRICE FOR CONFERENCE 40€