Chapter Three: Introduction to the Eurocodes

1.1 Background

The Eurocodes are a set of structural design standards, developed by CEN (European Committee for Standardization) over the last 30 years, to cover the design of all types of structures in steel, concrete, timber, masonry and aluminum.

In the UK, they are published by BSI (British Standards Institution) 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.

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 aluminum 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.

**Structural Eurocodes- an overview**

- **BS EN 1990, Eurocode 0**: Basis of Structural Design
  - Structural safety, serviceability and durability

- **BS EN 1991, Eurocode 1**: Actions on Structures
  - Actions on structures

- **BS EN 1992, Eurocode 2**: Concrete
  - BS EN 1993, Eurocode 3: Steel
  - BS EN 1994, Eurocode 4: Composite
  - BS EN 1995, Eurocode 5: Timber
  - BS EN 1996, Eurocode 6: Masonry
  - BS EN 1999, Eurocode 9: Aluminum
  - Design and detailing

- **BS EN 1997, Eurocode 7**: Geotechnical design
- **BS EN 1998, Eurocode 8**: Seismic design
  - Geotechnical and seismic design
### EN 1990 Parts

<table>
<thead>
<tr>
<th>Standard Number</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>EN 1990:2002</td>
<td>Eurocode - Basis of structural design</td>
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</tbody>
</table>

### EN 1991 Parts

<table>
<thead>
<tr>
<th>Standard Number</th>
<th>Description</th>
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<tbody>
<tr>
<td>EN 1991-3:2006</td>
<td>Eurocode 1: Actions on structures - Part 3: Actions induced by cranes and machinery</td>
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<tr>
<td>EN 1993 Parts</td>
<td>Description</td>
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<td>---------------</td>
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<tr>
<td>EN 1993-1-7:2007</td>
<td>Eurocode 3: Design of steel structures - Part 1-7: Strength and stability of planar plated structures subject to out of plane loading</td>
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</tbody>
</table>
The Eurocode Parts contain two distinct types of statement

- **Principles**
- **Application Rules**

The **Principles** must be followed, to achieve compliance; the **Application Rules** 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.

**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.

1.4 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

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:

<table>
<thead>
<tr>
<th>Eurocode Subscript</th>
<th>Definition</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>$E_d$</td>
<td>Design value of an effect</td>
<td>$M_{Ed}$ Design bending moment</td>
</tr>
<tr>
<td>$R_d$</td>
<td>Design resistance</td>
<td>$M_{Rd}$ Design resistance for bending</td>
</tr>
<tr>
<td>$el$</td>
<td>Elastic property</td>
<td>$W_{el}$ Elastic section modulus</td>
</tr>
<tr>
<td>$pl$</td>
<td>Plastic property</td>
<td>$W_{pl}$ Plastic section modulus</td>
</tr>
</tbody>
</table>

**Geometrical axes**

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

![Diagram](image)

- **Major axis**
- **Minor axis**
- **Longitudinal axis of element**
1.5 **Basis of structural design (BS EN 1990)**

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.

### 1.5.1 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.

### 1.5.2 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.

1.5.3 Basic variables

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 of an action is given for each class of action, in relation to its probability of occurrence.

1.5.4 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,
- applied to effects of actions (to represent uncertainty in modelling) and to;
- applied 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:
\( \gamma_f \) applied as a multiplier to the characteristic value of an action.

\( \gamma_M \) applied as a divisor to the characteristic value of a material property.

(member resistance).

**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.

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.