Eurocode - Basis of structural design

EN 1990 : Sections 3 & 4
EN 1990 : Section 3

Principles of limit states design
Requirements

SAFETY        SERVICEABILITY
of people /of structure
resistance       functions
stability        comfort

DURABILITY
fatigue

appearance
Verification

DESIGN SITUATIONS
persistent, transient, accidental, seismic

AGENTS
gravity, wind, solar radiation, earthquake...

ACTIONS
load, pressure, temperature, ground acceleration...

COMBINATIONS OF ACTIONS
actions likely to occur simultaneously

EFFECTS
force, moment, rotation, displacement
ULTIMATE LIMIT STATES

rupture

collapse

loss of equilibrium

transformation into a mechanism

failure caused by fatigue
SERVICEABILITY LIMIT STATES

deformations

vibrations

cracks

damages adversely affecting use
Design procedure

<table>
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<th>REQUIREMENTS</th>
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<td>DURABILITY</td>
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| ULTIMATE LIMIT STATES | SERVICEABILITY LIMIT STATES |
Limit state design

Structural and load models (physical or mathematical) using design values for

- actions
- material or product properties
- geometrical data

Load cases should be selected, identifying

- load arrangements,
- possible deviations
  from assumed directions and positions of actions,
- sets of deformations and imperfections,
that should be considered simultaneously
Verifications at limit states

ULTIMATE

• Resistance:
  \( E_d \leq R_d \) resistance

• Static equilibrium:
  \( E_{d,\text{dst}} \leq E_{d,\text{st}} \) stabilising actions

SERVICEABILITY

• Criterion C:
  \( E_d \leq C_d \) design criterion
# EN 1990 - Probabilistic methods

## Table: Consequences of Failure and Structural Reliability

<table>
<thead>
<tr>
<th>Class</th>
<th>Consequences Description</th>
<th>Structural Reliability</th>
</tr>
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<tbody>
<tr>
<td></td>
<td></td>
<td>Level III (full prob.)</td>
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<tr>
<td></td>
<td></td>
<td>$P_f$</td>
</tr>
<tr>
<td>CC3</td>
<td>high or very great</td>
<td>$10^{-7}$</td>
</tr>
<tr>
<td>CC2</td>
<td>medium and considerable</td>
<td>$10^{-6}$</td>
</tr>
<tr>
<td>CC1</td>
<td>low and small or negligible</td>
<td>$10^{-5}$</td>
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</table>

(1 year reference period)
EN 1990 : Section 4

Basic variables
Actions and environment influences
Actions and environment influences

CLASSIFICATIONS:

• **permanent** \( G \): self-weight, shrinkage, settlements, prestressing \( P \) (imposed force/deformation),...

• **variable** \( Q \): imposed loads, wind, snow, temperature, ...

• **accidental** \( A \): impacts, explosions, seismic actions ...

**NOTE**: water may be permanent or variable
snow, wind, seismic actions may be variable or accidental

• by **origin**: direct or indirect
• by **spatial variation**: fixed or free
• by **nature or structural response**: static or dynamic
Representative values of actions

Characteristic value (main representative value):

- mean value if variability small: \( G_k, P_m \)
- upper or lower value if variability not small:
  - \( G_{k,\text{inf}} \) (5 % fractile), \( P_{k,\text{inf}} \)
  - \( G_{k,\text{sup}} \) (95 % fractile, i.e. probability of exceedence 5 %), \( P_{k,\text{sup}} \)
  - \( Q_k \) (climatic actions: probability of exceedence 2 %/year)
  - \( A_{Ek} \) (seismic actions)

- nominal value

- value specified for an individual project: \( A_d \)
Other representative values of actions

**Combination values** \( \Psi_0 Q_k \)
- for ultimate limit states of permanent and transient design situation
- for irreversible serviceability limit states

**Frequent values** \( \Psi_1 Q_k \) (e.g. during 1 % of the reference period)
- for ultimate limit states of involving accidental actions
- for reversible serviceability limit states

**Quasi-permanent values** \( \Psi_2 Q_k \) (e.g. during 50 % of the period)
- for ultimate limit states involving accidental actions
- for reversible serviceability limit states
Material and product properties

Representative values from standardised tests:

- when a limit state verification is sensitive to variability:
  - **lower characteristic value** (5 % fractile)
    where a low value is unfavourable
  - **upper characteristic value** (95 % fractile, i.e. probability of exceedence 5 %)
    where a high value is unfavourable
- where statistical data are insufficient: **nominal values**
- **mean values** for structural stiffness and thermal expansion

Effects of repeated actions (fatigue) = reduction of resistance
Geometrical data

Representative values:

- **characteristic values** (a prescribed fractile) where statistical distribution is sufficiently known
- **directly design values** (e.g. imperfections)

Tolerances for connected parts shall be mutually compatible
Code of Hammurabi (1760 BC)

• “If a builder build a house for some one, and does not construct it properly, and the house which he built fall in and kill its owner, then that builder shall be put to death.” (Art. 229)

• “If it ruin goods, he shall make compensation for all that has been ruined, and inasmuch as he did not construct properly this house which he built and it fell, he shall re-erect the house from his own means.” (Art. 232)
Civil Code of Napoleon (1804)

“If the edifice, built at a set price, perish in whole or in part by defect in its construction, even by defect in the foundation, the architect and the contractor are responsible therefor for ten years.” (Art. 1792)
Applicability of standards
(calculation methods, e.g. Eurocodes)

<table>
<thead>
<tr>
<th>Source</th>
<th>CIVIL CODE</th>
<th>LAW</th>
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</thead>
<tbody>
<tr>
<td>Technical requirements</td>
<td>JURISPRUDENCE of the COURTS</td>
<td>REGULATIONS</td>
</tr>
<tr>
<td>Application</td>
<td>a posteriori</td>
<td>a priori</td>
</tr>
<tr>
<td>Standards (e.g. Eurocodes)</td>
<td>Referenced good practice but not compulsory</td>
<td>Compulsory only if imposed by regulation</td>
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</table>
Construction products directive

CONSTRUCTION WORKS

Requirements (CPD interpretative documents) ↓↑ Performances (CE marking)

CONSTRUCTION PRODUCTS

National

European Union
Eurocodes : “a harmonised tool”

“Beyond the defense of national positions,” like Jean MONNET wrote in his Memoirs, “something new and strong comes into living within the team : it’s the European spirit which is the fruit of the work together and, above all, of the need to come to a common conclusion after the discussion.”
“the European spirit”
Merci de votre attention