Further Developments of Eurocodes

And Geotechnical Issues

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10 Eurocodes – 58 Parts – 5320 pages

EN 1990
109 pages

EN 1995
269 pages

EN 1991
783 pages

EN 1992
469 pages

EN 1993
1470 pages

EN 1994
334 pages

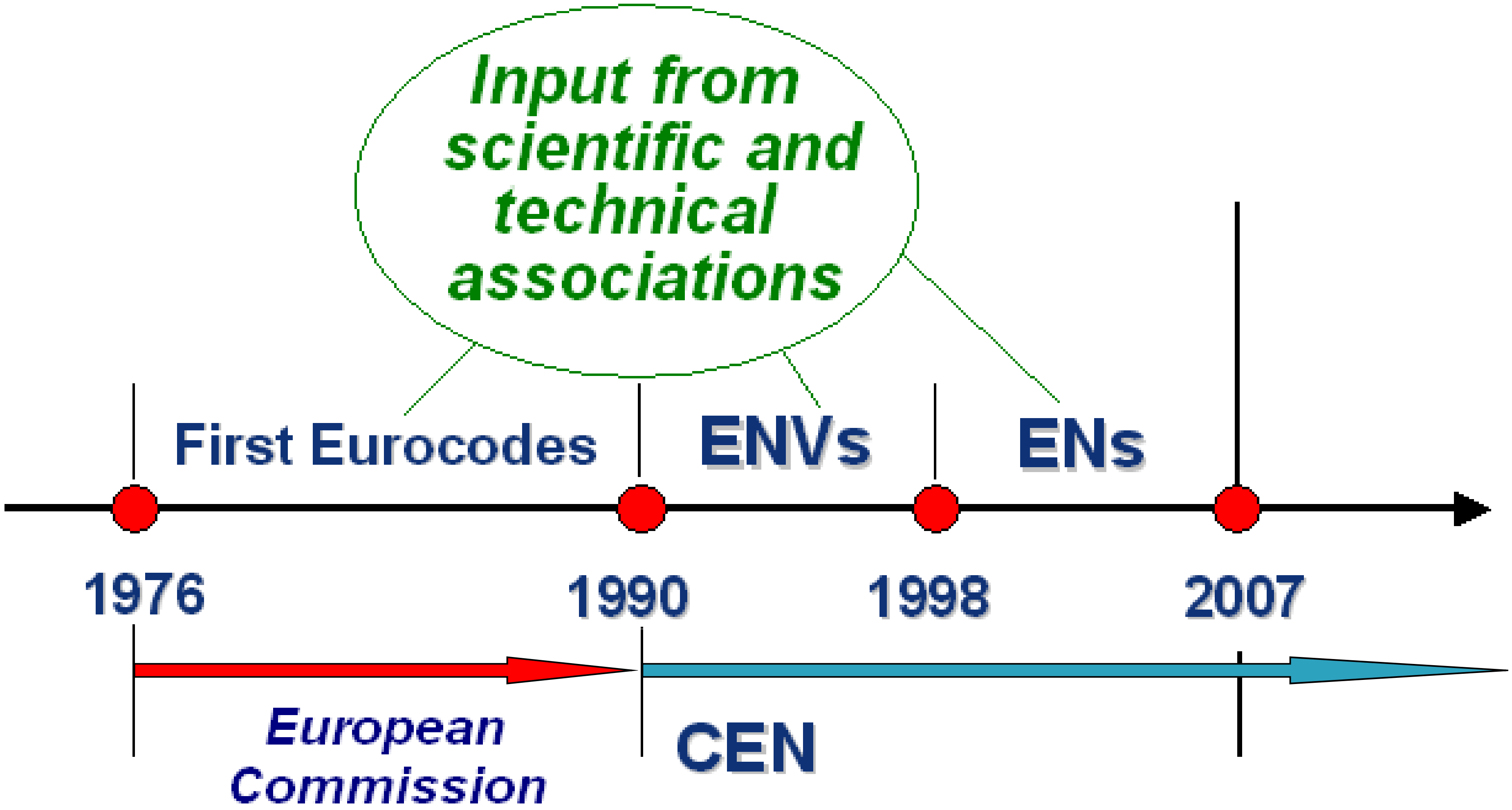
EN 1996
276 pages

EN 1997
371 pages

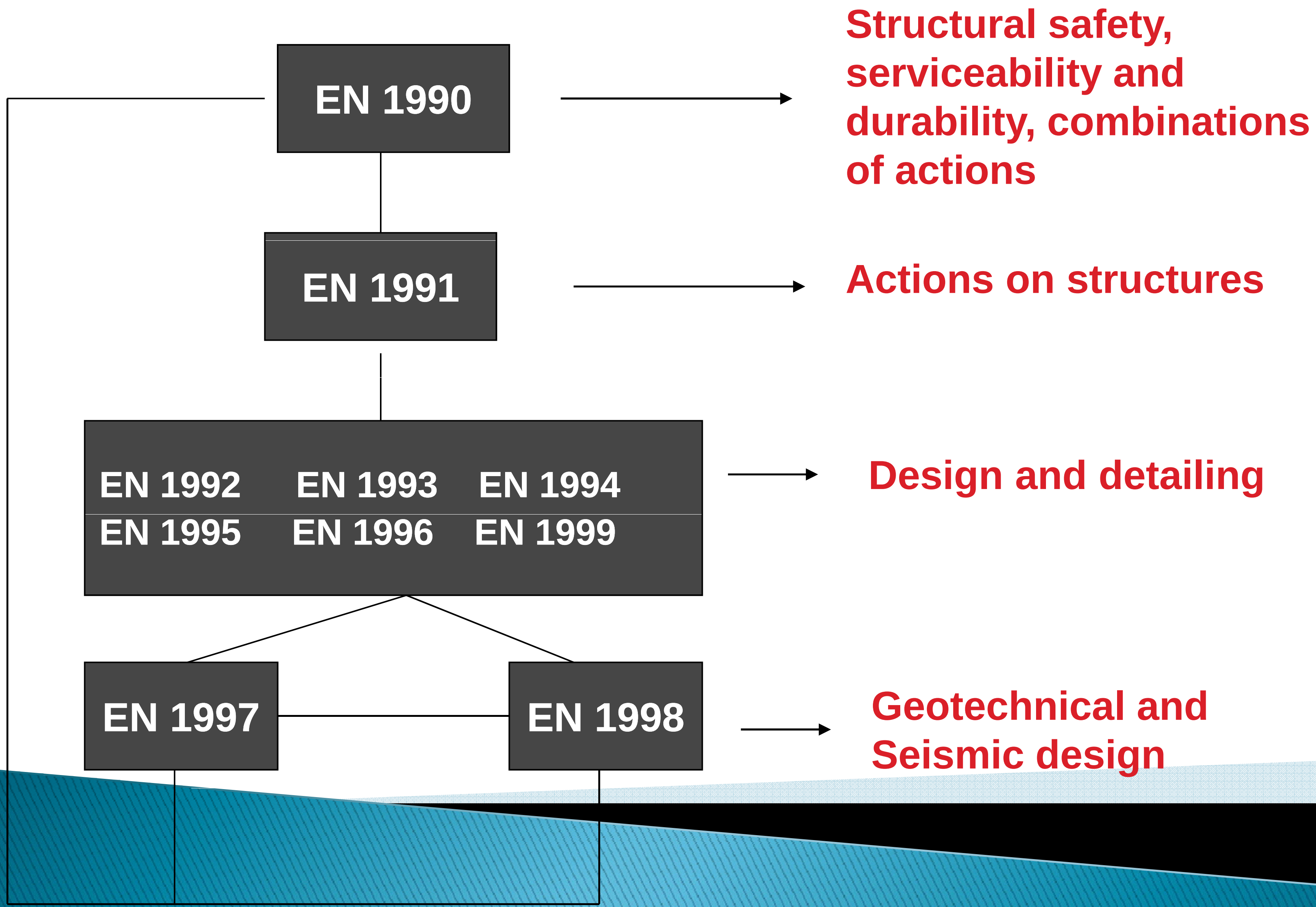
EN 1998
686 pages

EN 1999
553 pages

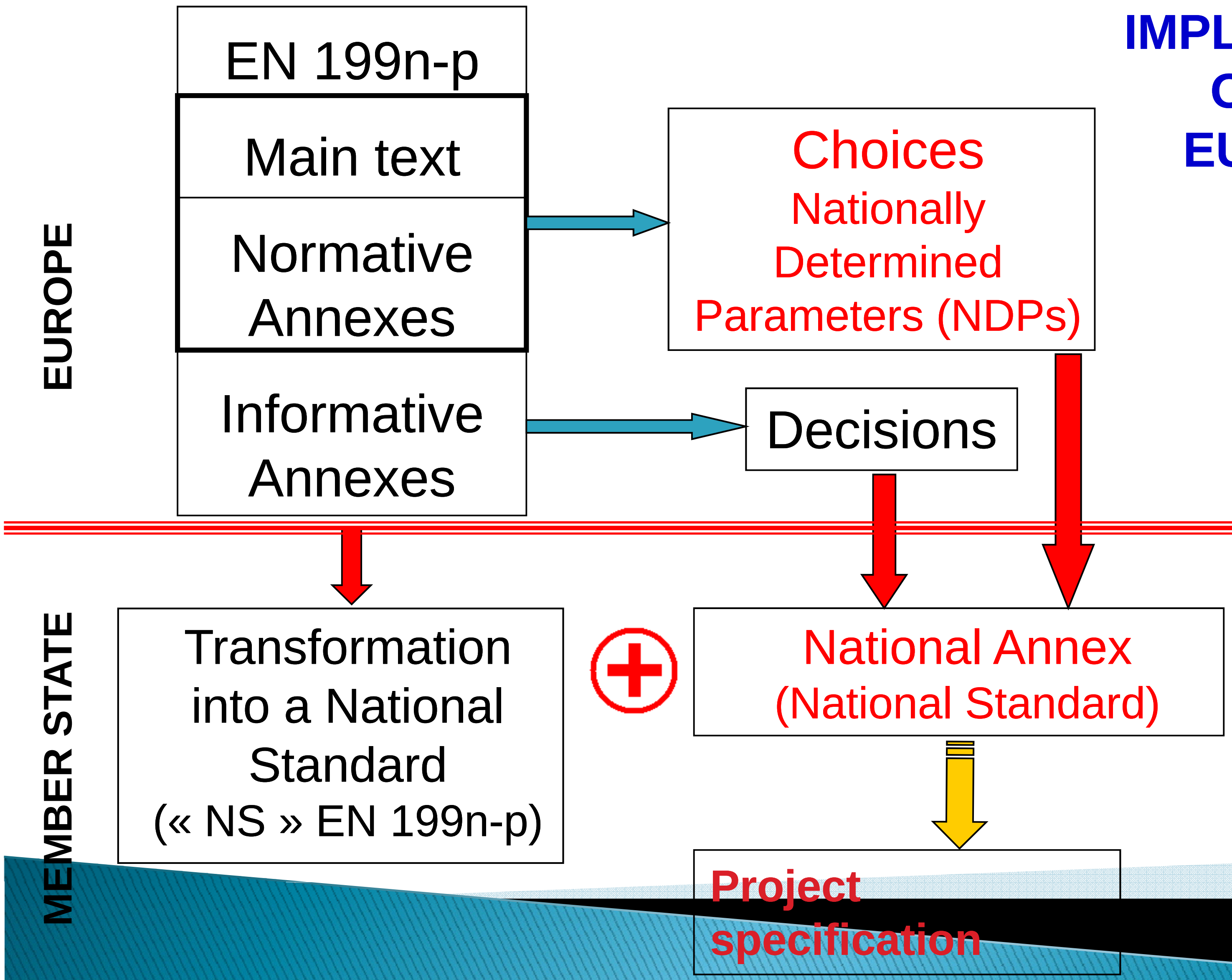
Development of the present generation of Eurocodes



EN 1990 Basis of Structural design


EN 1990
Structural safety, serviceability and durability, combinations of actions
EN 1991
Actions on structures
EN 1992 EN 1993 EN 1994
EN 1995 EN 1996 EN 1999
Design and detailing
EN 1997
EN 1998
Geotechnical and Seismic design

IMPLEMENTATION OF THE EN EUROCODES



PROMOTION / EDUCATION

MAINTENANCE

HARMONIZATION (NDPs)

FURTHER DEVELOPMENT

Next Steps

Evolution of the Eurocodes :

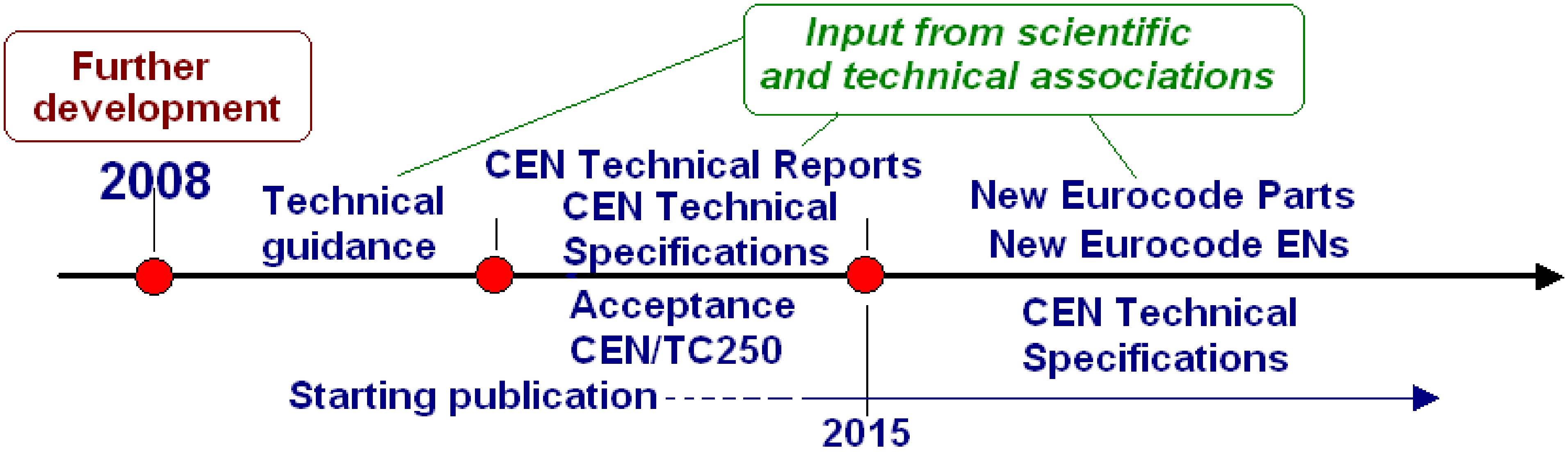
Preparation of the new generation of Eurocodes

Development of scientific and technical reports for :

- **for new Eurocode Parts,**
- **for new Eurocodes ENs**

New Materials and/or Techniques

- Existing Structures
- Structural Glass
- FRP
- Membrane Structures
- Robustness


Further development
2008
Technical guidance
Input from scientific and technical associations
CEN Technical Reports
CEN Technical Specifications
Acceptance CEN/TC250
Starting publication
2015
New Eurocode Parts
New Eurocode ENs
CEN Technical Specifications

FROM THE CPD TO THE FUTURE CONSTRUCTION PRODUCTS REGULATION

ANNEX I

Basic works requirements

Construction works as a whole and in their separate parts must be fit for their intended use.

Subject to normal maintenance, basic works requirements must be satisfied for an economically reasonable working life.

Basic works requirements

1. Mechanical resistance and stability
2. Safety in case of fire
3. Hygiene, health and the environment
4. Safety in use
5. Protection against noise
6. Energy economy and heat retention
7. Sustainable use of natural resources

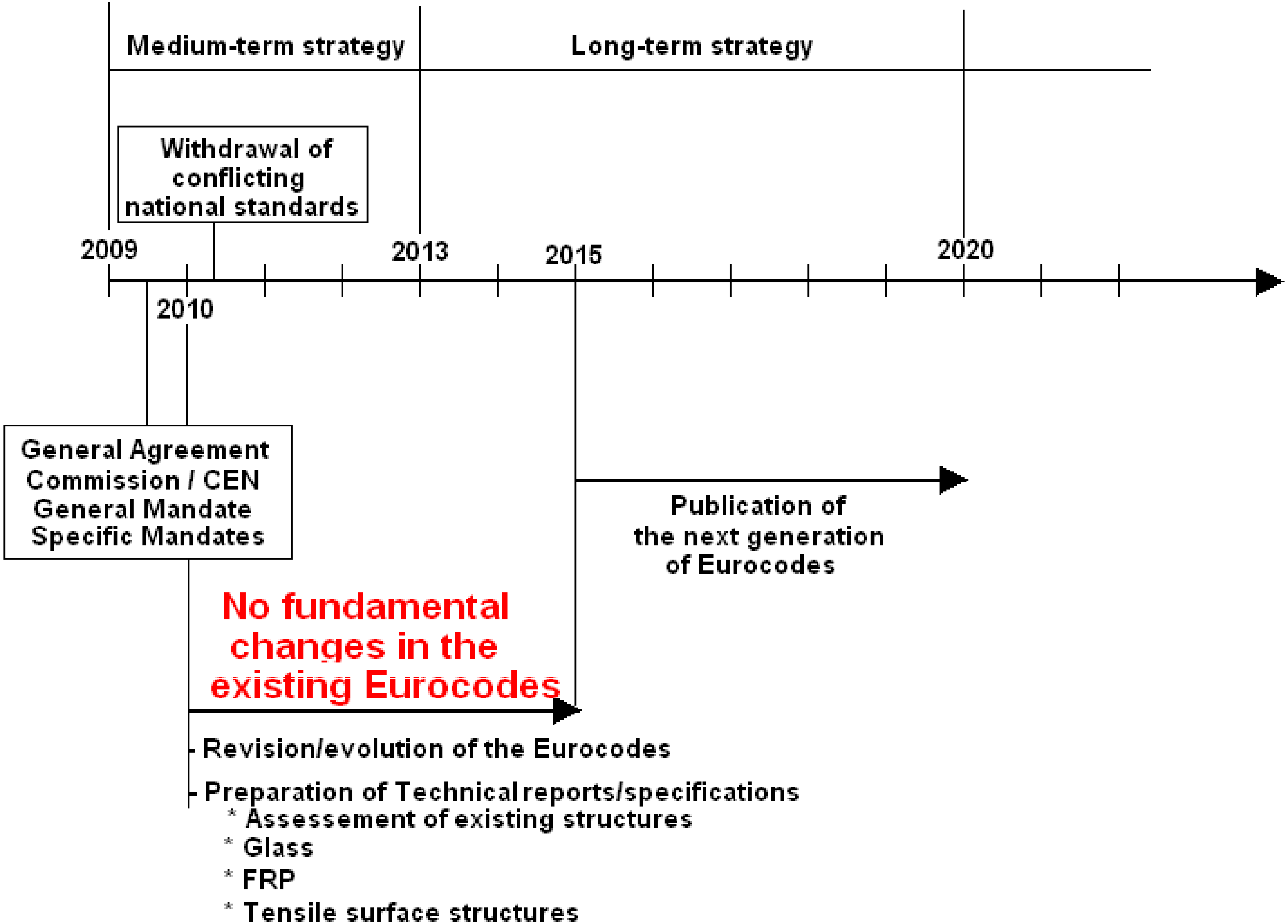
7. Sustainable use of natural resources

The construction works must be designed, built and demolished in such a way that the use of natural resources is sustainable and ensure the following:

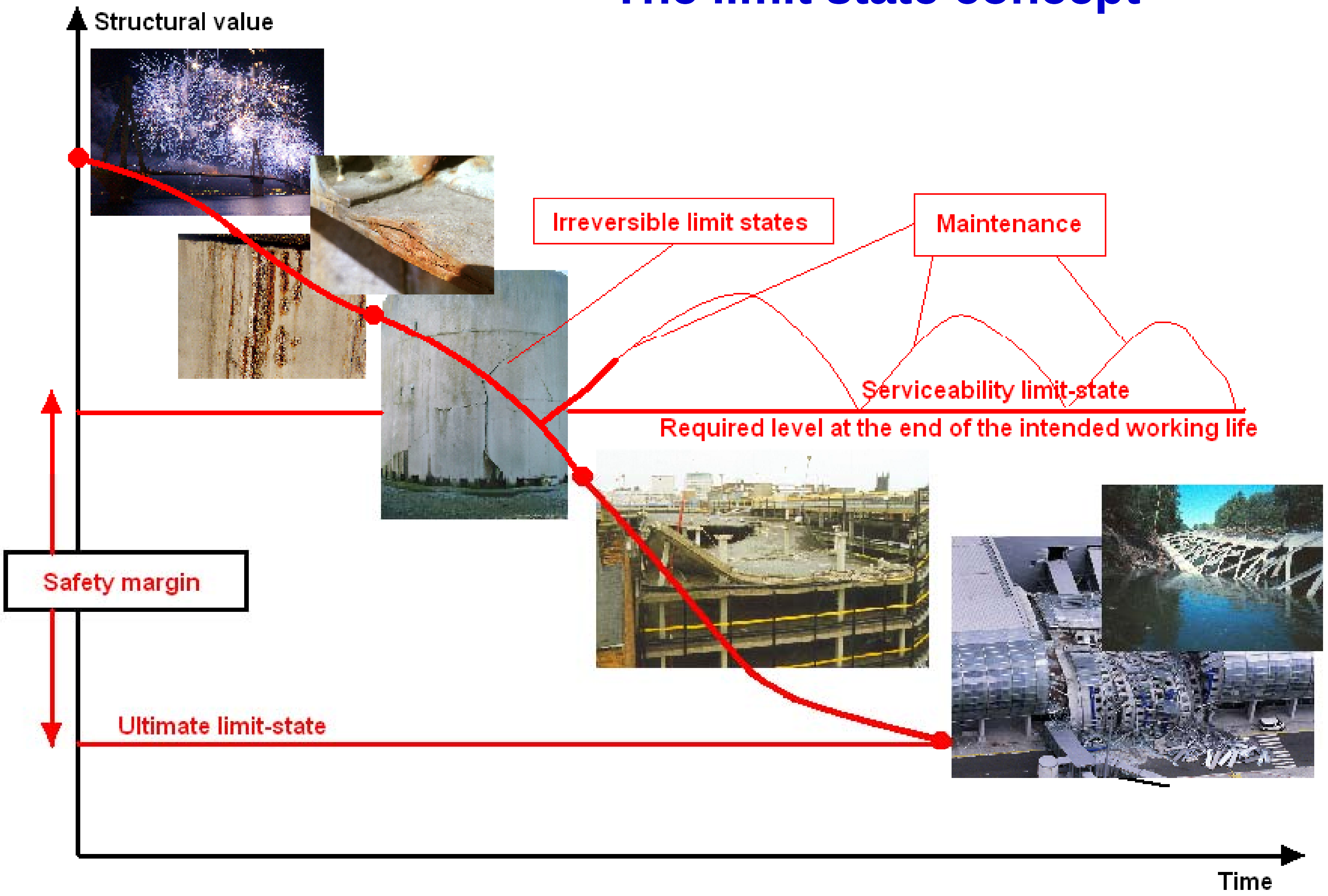
(a) recyclability of the construction works, their materials and parts after demolition;

(b) durability of the construction works;

(c) use of environmentally compatible raw and secondary materials in the construction works.

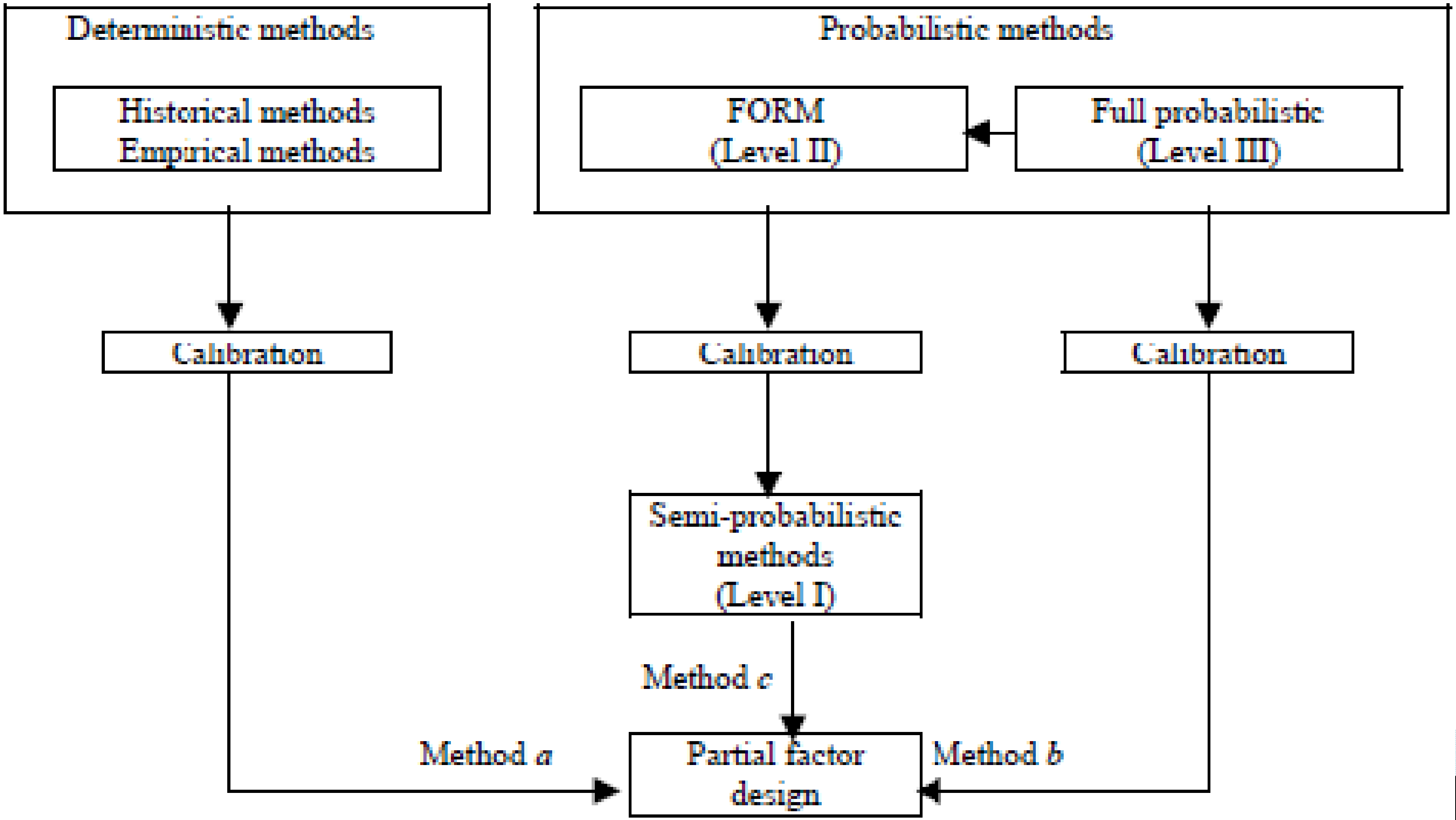

Medium-term strategy
Long-term strategy
Withdrawal of conflicting national standards
2009
2010
2013
2015
2020
General Agreement
Commission / CEN
General Mandate
Specific Mandates
Publication of the next generation of Eurocodes
No fundamental changes in the existing Eurocodes
- Revision/evolution of the Eurocodes
- Preparation of Technical reports/specifications
* Assessement of existing structures
* Glass
* FRP
* Tensile surface structures

The limit state concept



General Principles of Structural Reliability in the Eurocodes

Overview of reliability methods



The semi-probabilitic format for the verification of construction works

The semi-probabilistic approach is based on rules, partially deterministic, that introduce safety at the following levels :

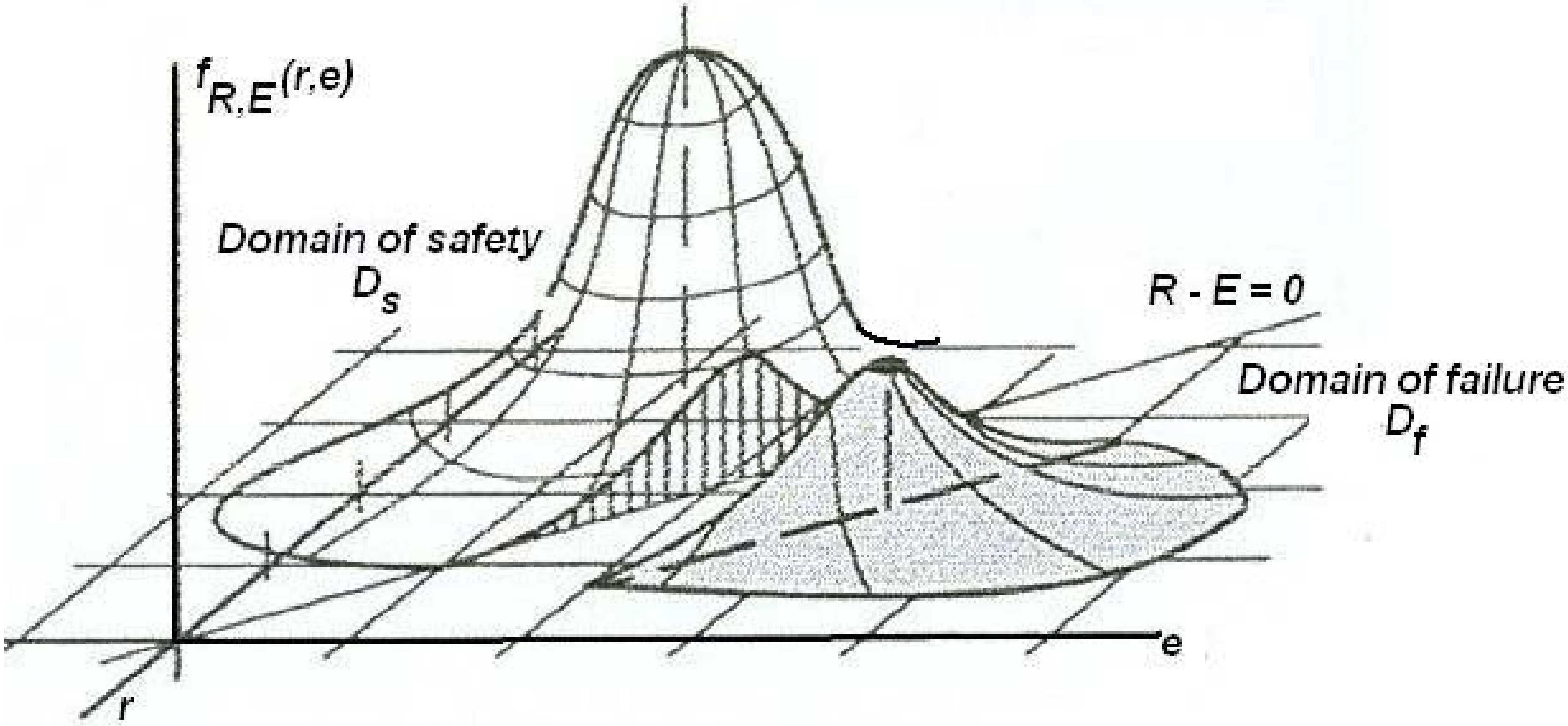
- **Selection of appropriate representative values of the various random parameters (actions and resistances)**
- **Application of partial factors to these parameters**
- **Introduction of safety margins, more or less appearent, in the various models (models of actions, action effects and resistances).**

THE BASIC MODEL WITH TWO VARIABLES

E	Effect of actions (for example, bending moment)
R	Resistance
$Z = R - E$	Safety margin
$Z \leq 0$	Condition of failure
$r - e = 0$	Limit-state function
$p_f = P(Z \leq 0)$	Probability of failure
$f_{E,R}(e,r)$	Joint probability density of E and R

Probability of failure $$p_f = \iint_{D_f} f_{E,R}(e,r)\,de\,dr$$

Calculation of the probability of failure



Reliability approach

Assumptions :

R, E follow Normal laws characterised by (μ_R, σ_R) and (μ_E, σ_E)

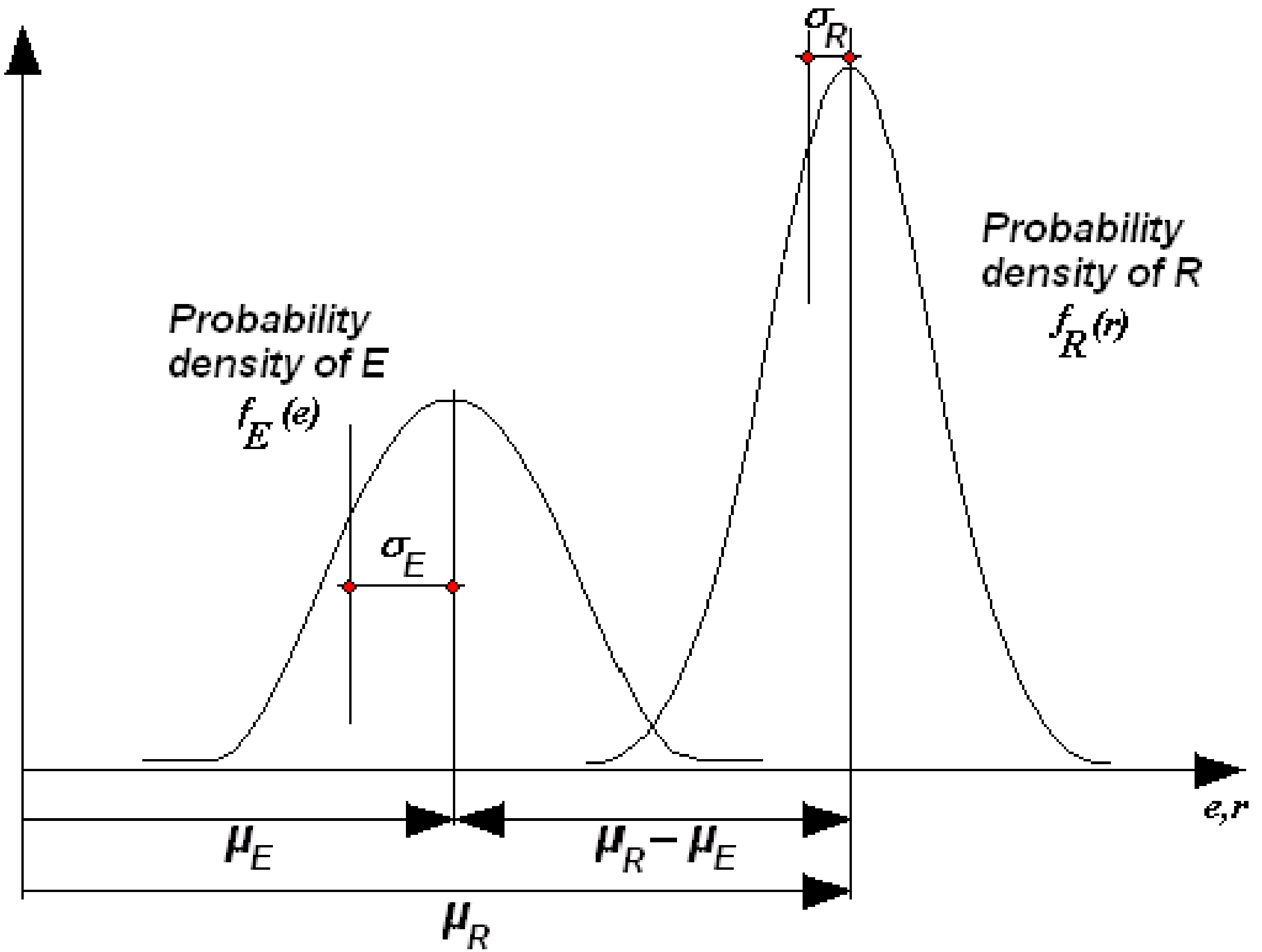
$\Rightarrow$ Z = R – E follows a Normal law of characteristics :

$$\mu_Z = \mu_R - \mu_E \quad ; \quad \sigma_Z = \sqrt{\sigma_E^2 + \sigma_R^2}$$

$$F(z) = \Phi\left(\frac{z - \mu_z}{\sigma_z}\right) \qquad \Phi(x) = \frac{1}{\sqrt{2\pi}} \int_{-\infty}^{x} e^{-\frac{t^2}{2}} dt$$

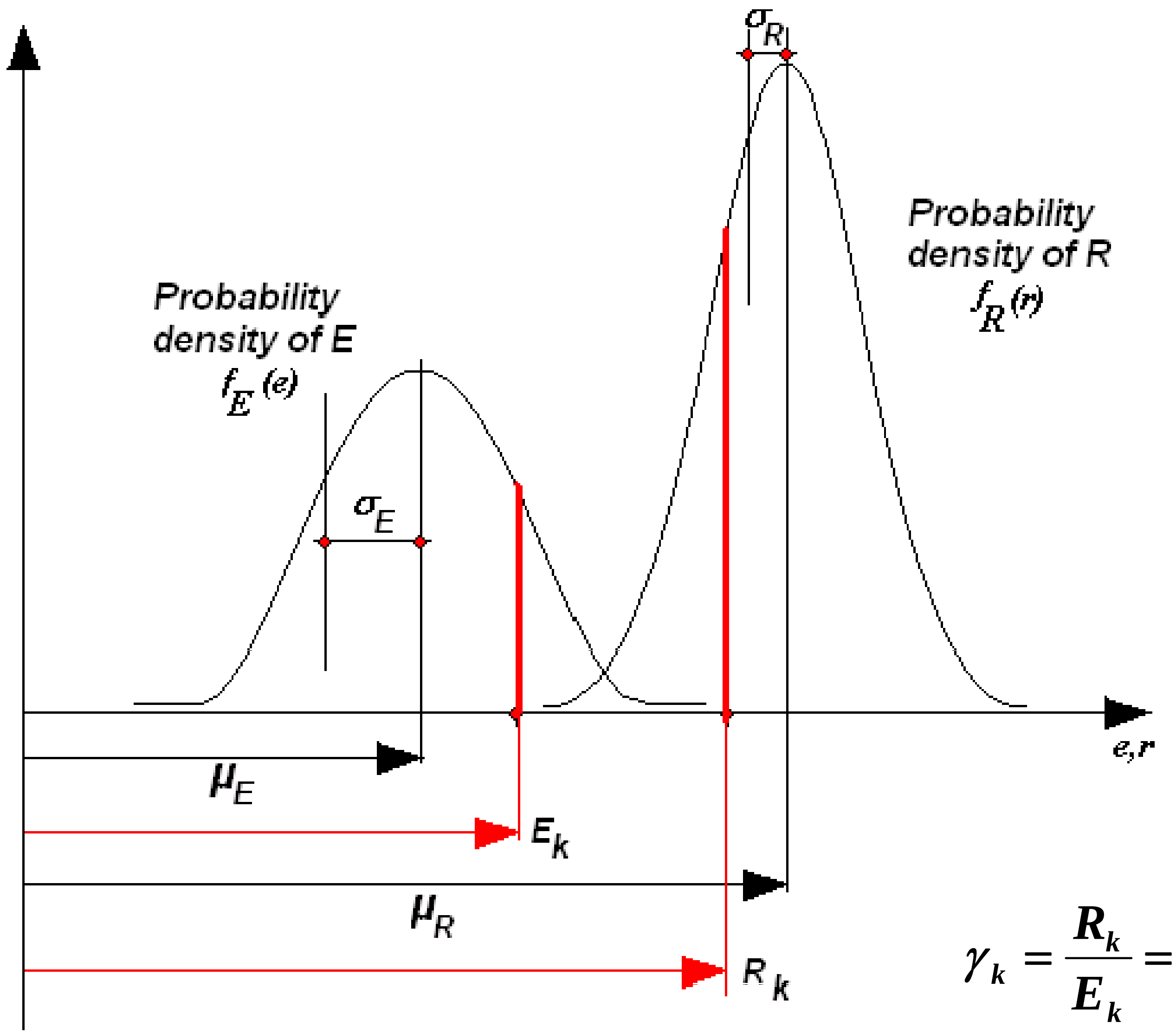
Standard Normal law

A first approach of safety



Central safety factor

$$\bar{\gamma} = \frac{\mu_R}{\mu_E}$$



Coefficients of variation

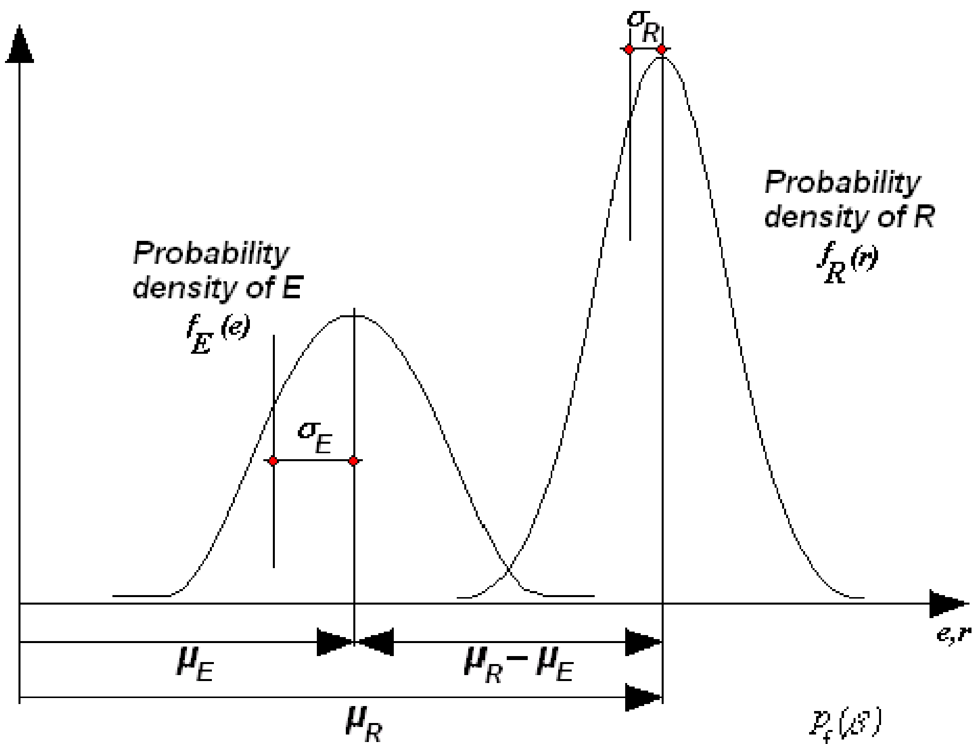
$$V_R = \frac{\sigma_R}{\mu_R} \quad V_E = \frac{\sigma_E}{\mu_E}$$

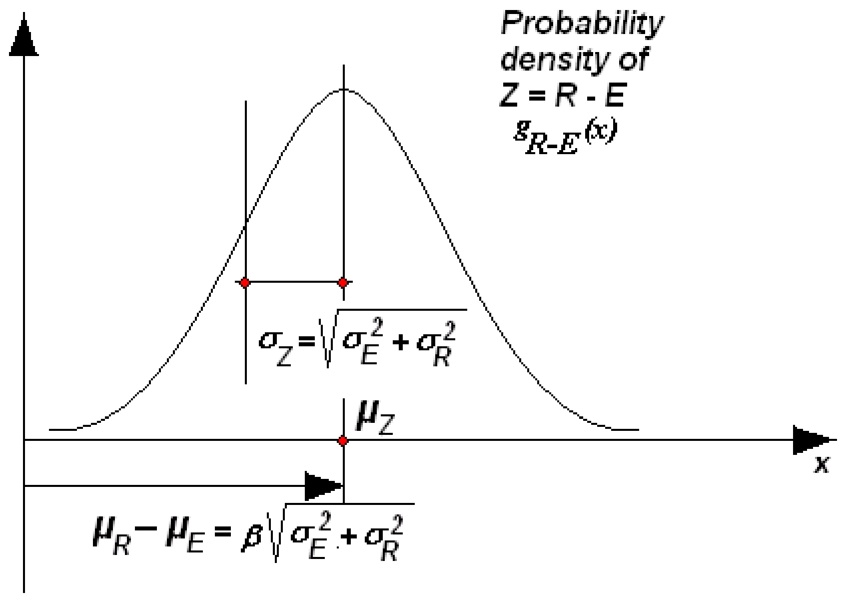
$$E_k = \mu_E + k_E \sigma_E$$

$$R_k = \mu_R - k_R \sigma_R$$

« Characteristic safety factor »

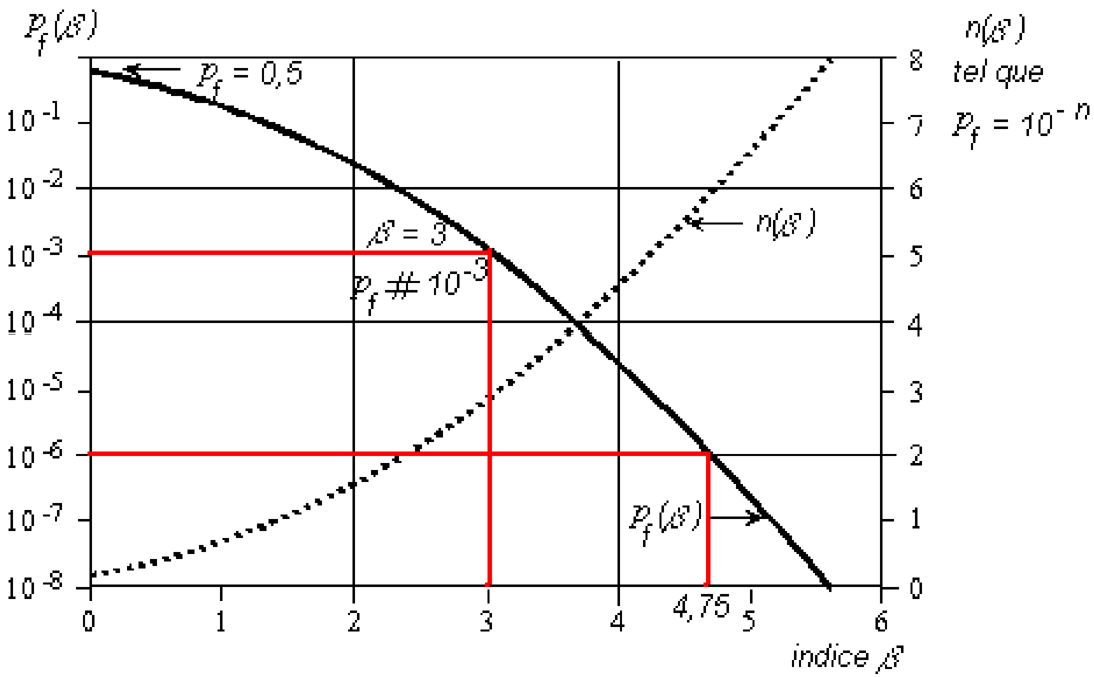
$$\gamma_k = \frac{R_k}{E_k} = \frac{\mu_R - k_R\sigma_R}{\mu_E + k_E\sigma_E} = \bar{\gamma} \times \frac{1 - k_R V_R}{1 + k_E V_E}$$





$$p_f = \Phi(-\beta)$$

$$\beta = \frac{\mu_R - \mu_E}{\sqrt{\sigma_R^2 + \sigma_E^2}}$$



Central safety factor $\bar{\gamma} = \frac{\mu_R}{\mu_E}$

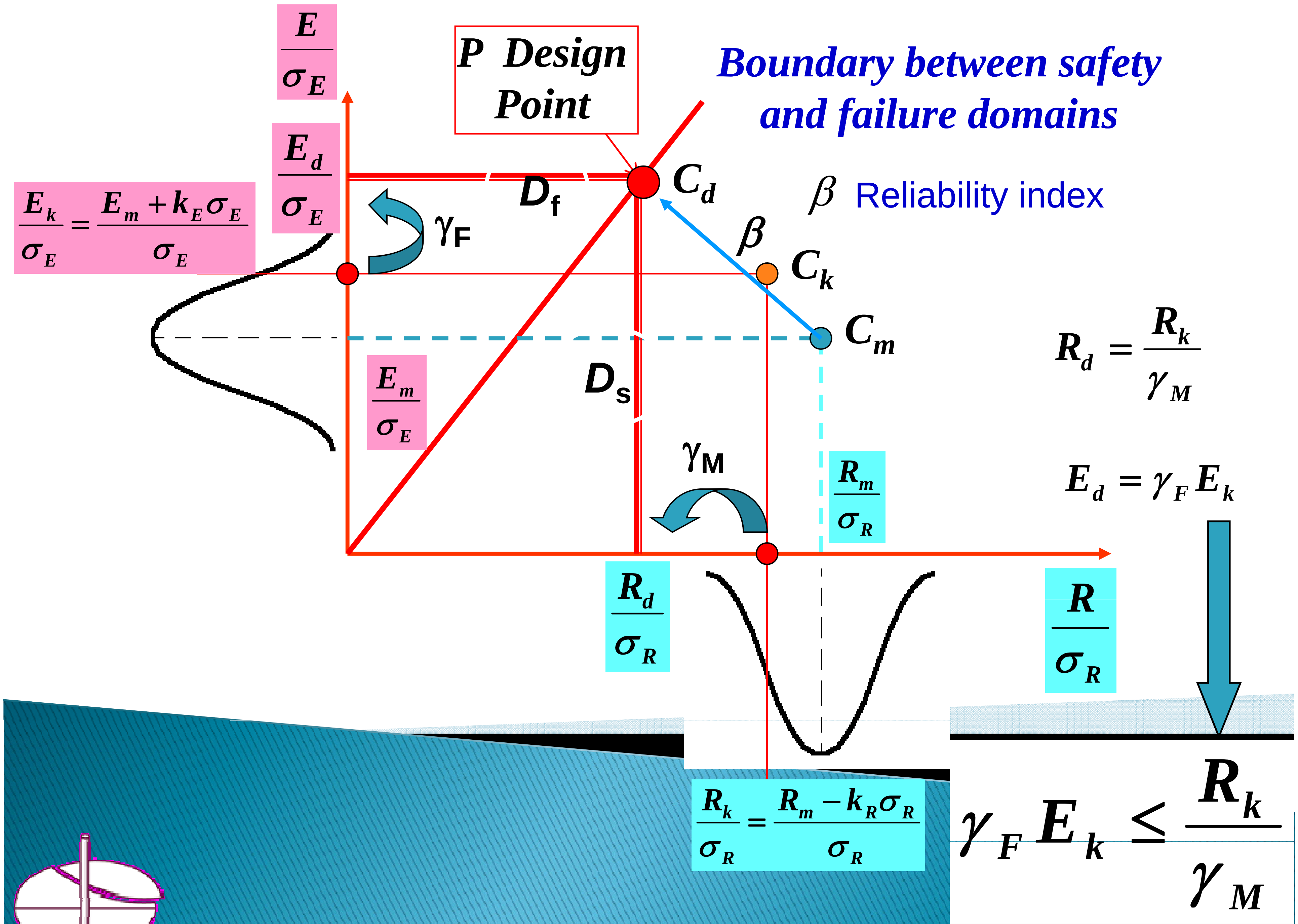
Coefficients of variation $V_R = \frac{\sigma_R}{\mu_R} \quad V_E = \frac{\sigma_E}{\mu_E}$

Reliability index $\beta = \frac{\mu_R - \mu_E}{\sqrt{\sigma_R^2 + \sigma_E^2}} = \frac{\bar{\gamma} - 1}{\sqrt{V_E^2 + \bar{\gamma}^2 V_R^2}} \quad \Rightarrow \quad \bar{\gamma} = f(\beta)$

Characteristic safety factor $\gamma_k == \frac{R_k}{E_k} = \frac{\mu_R - k_R \sigma_R}{\mu_E + k_E \sigma_E} = \bar{\gamma} \times \frac{1 - k_R V_R}{1 + k_E V_E}$

Partial factor design $\gamma_F E_k \leq \frac{R_k}{\gamma_M} \quad \Rightarrow \quad \gamma_F \times \gamma_M \leq \gamma_k$

$$\beta \rightarrow \bar{\gamma} \rightarrow \gamma_k \rightarrow (\gamma_F, \gamma_M) / \gamma_F \times \gamma_M \leq \gamma_k$$



$\frac{E}{\sigma_E}$
P Design Point
Boundary between safety and failure domains
$\frac{E_d}{\sigma_E}$
$\frac{E_k}{\sigma_E} = \frac{E_m + k_E \sigma_E}{\sigma_E}$
D_f
C_d
β Reliability index
γ_F
β
C_k
C_m
$R_d = \frac{R_k}{\gamma_M}$
$\frac{E_m}{\sigma_E}$
D_s
γ_M
$\frac{R_m}{\sigma_R}$
$E_d = \gamma_F E_k$
$\frac{R_d}{\sigma_R}$
$\frac{R}{\sigma_R}$
$\frac{R_k}{\sigma_R} = \frac{R_m - k_R \sigma_R}{\sigma_R}$
$\gamma_F E_k \leq \frac{R_k}{\gamma_M}$

A tentative application

Sliding limit state : $$H \leq \frac{V \tan\varphi}{\gamma}$$

Where :

H = horizontal component of resultant forces

V = vertical component of resultant forces

φ = internal friction angle

γ= safety factor

Safety margin : $$Z = V \tan\varphi - H$$

V, H and tanφ are assumed independant and following a Normal law.

$$\mu_Z = \mu_V \times \mu_{\tan\varphi} - \mu_H$$

$$\sigma_Z^2 = \sigma_{V\tan\varphi}^2 + \sigma_H^2 = \sigma_V^2\sigma_{\tan\varphi}^2 + \mu_{\tan\varphi}^2\sigma_V^2 + \mu_V^2\sigma_{\tan\varphi}^2 + \sigma_H^2$$

Where V_V and $V_{\tan\varphi}$ are the coefficients of variation of V and $\tan\varphi$. Adopting the notation :

$$\mu_H = \lambda\mu_V \times \mu_{\tan\varphi}$$

The reliability index is :

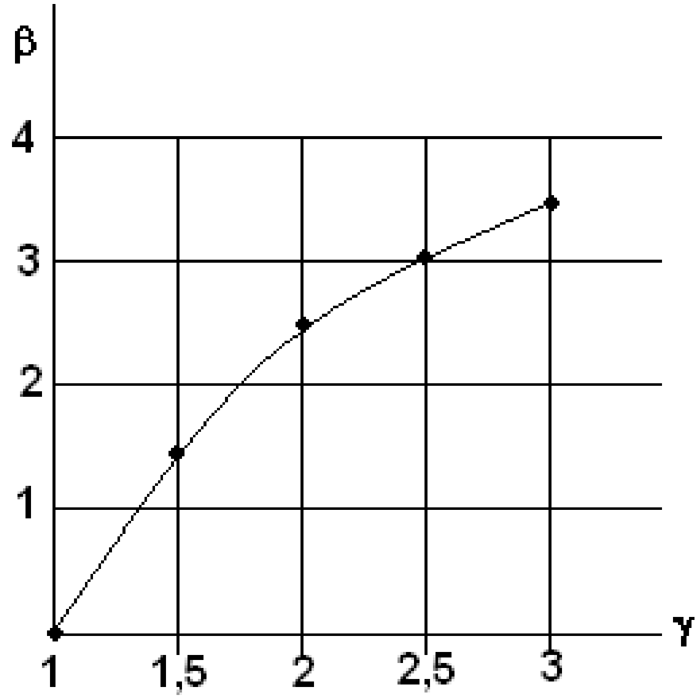
$$\beta = \frac{\mu_Z}{\sigma_Z} = \frac{\mu_V \times \mu_{\tan\varphi} - \mu_H}{\sqrt{\sigma_V^2\sigma_{\tan\varphi}^2 + \mu_{\tan\varphi}^2\sigma_V^2 + \mu_V^2\sigma_{\tan\varphi}^2 + \sigma_H^2}} = \frac{1-\lambda}{\sqrt{V_V^2 + V_{\tan\varphi}^2 + V_V^2 V_{\tan\varphi}^2 + \lambda^2 V_H^2}}$$

With :

$$V_V = 0{,}1 \quad V_{\tan\varphi} = 0{,}15 \quad V_H = 0{,}20$$

$$\beta \cong \frac{1-\lambda}{0{,}1\sqrt{3{,}25+4\lambda^2}} = \frac{\gamma-1}{0{,}1\sqrt{3{,}25\gamma^2+4}}$$

With $\gamma = \dfrac{1}{\lambda}$



Assuming : $H_d = 1{,}35\mu_H \quad \gamma = 1{,}2(ULS) \quad \gamma H_d = 1{,}62\mu_H$

$$\Rightarrow \beta \cong 1{,}8 \quad \Rightarrow p_f \cong 0{,}06$$

A few basic conclusions :

1) Probability of failure in geotechnical design, with safety factors usually adopted, turns out to be higher than for structures, which contradicts experience.

2) The basic random variables in geotechnical design are of a very different nature than the basic random variables in structural design.

3) In a structural member, the effect of actions is far more scattered than the resistance. In a bridge foundation, for example, the effect of actions, mainly due to permanent loads, is far less scatterred than the bearing capacity of ground. The two types of problems are very different.

4) A probabilistic approach of geotechnical problems is not useless. It is necessary to compare the reliability levels in geotechnical design and in structural design, and to give the right interpretation of observed differences.

Personal conclusions : three dreams

1) **The future Eurocode 7 should be enough developed to avoid the need to draft national accompanying standards**

2) **A background document would be very useful to explain why the reliability levels obtained by using the usual safety factors are in general acceptable**

3) **Try to harmonize the reliability levels corresponding to the 3 geotechnical approaches defined in EN 1990**

The Eurocodes : finally a nice meal, even the restaurant is not always comfortable

Thank you for your attention