Robustness of Structures

COST Action TU0601

1ST WORKSHOP

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Draft Guideline to satisfy Robustness prescriptions in Structural Codes

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Works, Regulations and Products

Rules on Works
MS Competence

Rules on Products
Competence both of EC and MS

Different regulatory systems in Europe.

Performance-based or prescriptive regulations

Sometimes regulations on works and products are in the same provision

(Italian Decree 14.9.05)

Construction Controls Regimes have several sub-systems among EU

- Different Planning and building regulations prescriptive v. performance based
- design codes (Eurocodes implented differently through MS), approved documents, technical guides
- product standards and/or approvals
- permits and planning control
- inspection systems
- technical control / insurance
- supervision of works: architect/ engineer/ PS
- liability and insurance

Robustness provisions should consider the different regulations among MS and try to unify the approach

Rules on Works and Products

National Regulations

DIR 89/106
ENh,ETA

EUROCODES
NATIONAL ANNEXES

Guidelines, Instructions

Provisions in regulations should be given with a performance-based approach

Technical Specifications

MANDATORY

VOLUNTARY

STANDARDS

Enforced

Directives → Laws, Decrees

Mandate

EUROCODES

Ministero delle Infrastrutture

Robustness provisions

Italian Code DM 2005

Italian DM 2005

- Introduction of a design lifetime
- Introduction of different return periods for the environment actions as consistent with the design lifetime (different from EC)
- Introduction of a cost-benefit analysis in selecting the safety target levels
- Introduction of robustness analysis

DESIGN LIFETIME

Tab. 2.5.I - *Useful design life of various types of structures*

USEFUL DESIGN LIFE (years)	TYPE OF STRUCTURE
10	Temporary structures – Structures at the construction stage
≥ 10	Replaceable structural components (joints, bearings, etc.)
50	Class 1 structures
100	Class 2 structures

The Client and the Designer, must jointly declare the useful life of the structure in the design.

CLASSES OF IMPORTANCE

Structures are divided into two importance classes defined as follows:

- *Class 1:* useful life of 50 years, return period to consider for the natural phenomena involved of 500 years. This class shall include structures whose normal use anticipates crowds, which have no contents hazardous to the environment, and which have no essential public and social functions, industries with non-dangerous activities and road and railway networks whose blockage will not cause emergency situations.
- *Class 2:* useful life of 100 years, return period to consider for the natural phenomena involved of 1000 years. This class shall include buildings whose normal use anticipates significant crowds, industries with activities hazardous to the environment, road and railway networks whose blockage will cause emergency situations and structures with public or important strategic functions, or essential social functions.

The decision of which class to assign to a structure shall be made by the Client in conjunction with the Designer, according to the guidelines provided by this regulation, and it must be clearly stated in the design.

RELIABILITY LEVELS

Table 2.5.II – *Upper limit of annual collapse probability for various ULS situations*

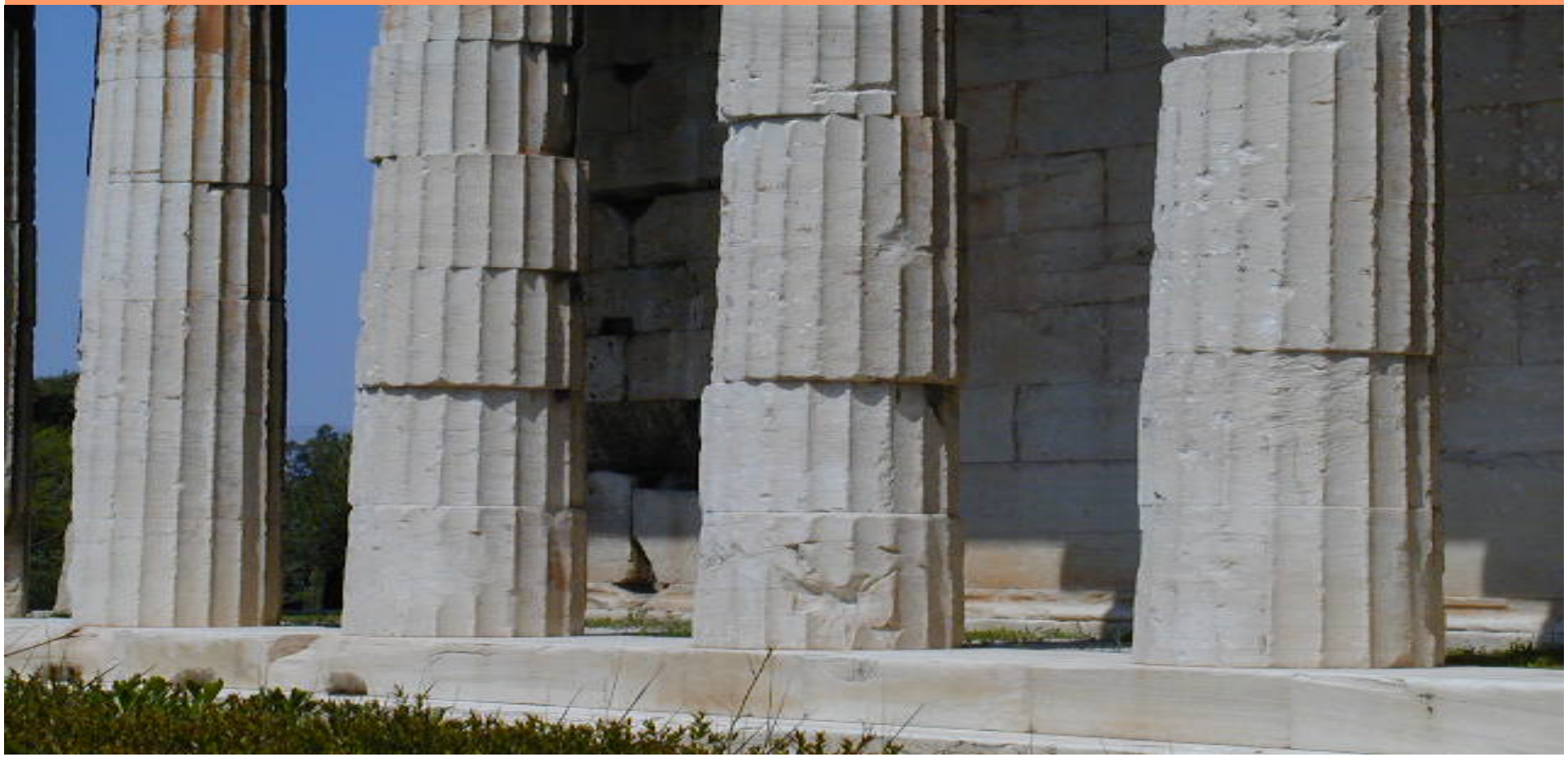
Relative cost of safety improvement measures	**CLASS 1**	**CLASS 2**
High	$\underline{P_f}$ $\leq 1 \times 10^{-4}$	$\underline{P_f}$ $\leq 1 \times 10^{-5}$
Low	$\leq 1 \times 10^{-5}$	$\leq 1 \times 10^{-6}$

ROBUSTNESS

In particular, according to the provisions of the specific rules for the various structural types, structures and structural elements must meet the following requirements:

- *safety with regard to ultimate limit states (ULS):* collapses, loss of equilibrium and serious total or partial instability which may endanger persons or result in the loss of goods, or cause serious environmental and social harm, or put the structure out of service;
- *safety with regard to serviceability limit states (SLS):* all the requirements which can guarantee the performance levels laid down for the operating conditions;
- *robustness with regard to accidental actions:* the ability to avoid damage disproportionate to the scale of the triggering cause such as a fire, explosion, impact or the consequences of human error.

Proposal Draft Guidelines to Satisfy the Robustness Prescriptions in Structural Codes



FAILURE IN WORKS

Failure are mostly due to:

Human Errors

Main cause (construction), more than 90% with expected actions

Design Errors

Load models unforeseen actions (fire, explosions), structural properties, over strong materials

Materials & Products

Not fit fo use, misuse of the intended-use (not relyable)

Material Degradation

Not durable, loss of maintenance

Structures shall be robust, relyable and durable → Need of a Quantification procedures of those performances

Robustness some basic concepts

- **Vulnerability**: estimate of the consequences of an initiating event
- **Risk assessment** requires a probabilistic model for the initiating event (hazard analysis) **Risk=Hazard x Vulnerability**
- When the latter is lacking, one proceeds by an analysis of **sensitivity** to perturbations: ROBUSTNESS

Need of Classes

- **Introduction of classes in regulations is needed**
  - **To create a frame where public Authorities can operate (financing, controls, permits…)**
  - **To allow simplified approaches in case of low storey buildings**
  - **For safety reasons in case of public infrastructures (schools, strategic buildings, hospitals…)**
- **The design approach depends on classes**
- **Prescriptions for robustness depends on classes to optimize the designer's effort**

INTRODUCTION OF CLASSES

CLASS OF WORK	Description
I	Structures in which **persons are only occasionally present**, agricultural buildings.
II	Structures, the use of which provides for **normal crowding**, **without environmentally hazardous contents** and **without essential public and social functions**. Industries performing non-environmentally hazardous activities. Civil works not falling within Class III or IV, rail networks, the interruption of which does not cause emergency situations. Dams, the collapse of which does **not give rise to significant consequences**.
III	Structures, the use of which provides for **significant crowding**. Industries performing **environmentally hazardous activities**. **Non-urban road networks** not falling within Class of use IV. Bridges and rail networks, the interruption of which causes emergency situations. Dams, the potential collapse of which **gives rise to significant consequences**.
IV	Structures with **public functions or strategically important structures**, including with reference to **civil protection management** in case of disaster. Industries performing activities that are particularly hazardous for the environment. Principlal road networks. Bridges and rail networks of are critical importance for maintaining communication routes. Dams connected with the functioning of aqueducts and of electricity generating plants.

Allowable Individual Risk in Codes

	Allowable Individual Risk (AIR) YEAR (2)
Works ULS Class 1(1)	10^{-4}
Works ULS Class 2(1)	10^{-5}
Works ULS Class 3	10^{-6}
Works ULS Class 4	10^{-7}
Railway tunnels (DM 05)	10^{-9}

(1) A risk analysis for Class 1 or 2 works is only theoretical

(2) The allowable risk could also be function of the relative cost of safety measures and/or consequence classes

Risk = Hazard x Vulnerability < AIR

Table 1: Action effectiveness vs. class

ACTIONS IMPOSED	CLASS			
	I	II	III	IV
Fraction of vertical loads (Height<100 m) (interpolate between 100 and 200m)	**-**	**0,5%**	**0,75%**	**1%**
Fraction of vertical loads (Height>200 m)	**-**	**0,05%**	**0,075%**	**0,1%**
Absence of structural members	**NO**	**NO**	**YES**	**YES**
Localized load on floors and walls	**2kN**	**2 kN**	**3kN**	**4kN**
Redundancy	**-**	**If required**	**YES**	**YES**
Explosion scenario or other complex scenarios	**If required Static equivalent analysis**	**If required Sensitivity An. Static equivalent analysis**	**YES Sensitivity An. Static equivalent analysis**	**YES Risk analysis Non linear**

ROBUSTNESS
Vs
PRODUCTS AND MATERIALS

ROBUSTNESS Vs PRODUCTS AND MATERIALS

Robustness is Linked to

"Quality"

Constant production, qualified FPC Certification (CPD)

Reliability

Small variation coefficients of technical characteristics, low percent defective, brittleness, fitness for use

Durability

Maintenance of the performances during WL, when normal maintenance is granted

RELIABILITY OF PRODUCTS AND MATERIALS

Reliability is Linked to(1)

Product Properties

Unchanged over a temperature range i.e. (-20° +60°)

Variation Coefficient

Less than i.e. (0,30)

Production defects

Less than 5%

Brittleness

Brittle behaviour shall be highlighted through testing

(1) Unless differently stated in ENh, ETAs or other technical specifications

DURABILITY OF PERFORMANCE

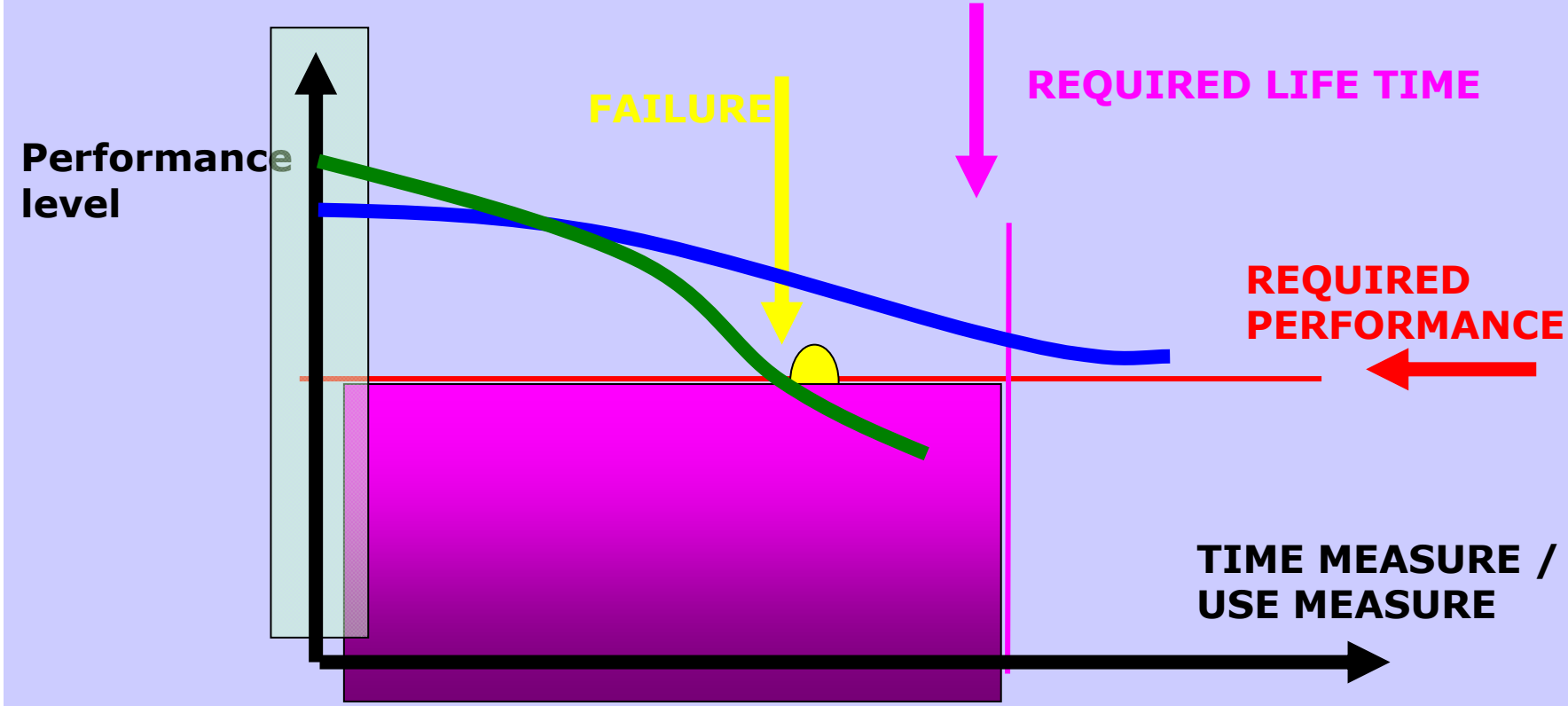


Table 2: Relation between working life and works/products

Assumed working life of works (years)		Working life of construction products to be assumed in ETAGs, ETAs and hENs (years)		
Category	**Years**	**Category**		
		Repairable or easily replaceable	Reparaible or replaceable with some more efforts	Lifelong[2]
Short	**10**	**10[1]**	**10**	**10**
Medium	**25**	**10[1]**	**25**	**25**
Normal	**50**	**10[1]**	**25**	**50**
Long	**100**	**10[1]**	**25**	**100**

[1] In exceptional and justified cases, e.g. for certain repair products, a working life of 3 to 6 yaers may be envisage (when agreed by EOTA TB or CEN respectively)

[2] When not reparaible or replaceable "easily" or with "some more efforts".

Thank you for your patience !

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