History and basic principles of EC7 and limit state design

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Structural engineers began to move away from Factors of Safety and towards Probability of Failure in the 1940s.

The design philosophy is now known as

Limit State Design

Load and Resistance Factor Design

Reliability Based Design

RBD now forms structural engineering design standards worldwide.

All the Structural Eurocodes use RBD.

EN 1997 Geotechnical Design (Eurocode 7) uses RBD.

Eurocode 7 applies to rock engineering design.

Ergo, rock engineering design to EC7 implements RBD principles

What is the origin of the Structural Eurocodes?

What is RBD/LSD/LRFD?

Eurocode chronology

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Year	Event
1957	Treaty of Rome
1971	*Public Procurements Directive 1971/305 issued*
1975	Eurocode development started
1980	International Inquiry with regard to construction codes performed
1984	First Eurocodes published
1989	*Construction Products Directive 1989/106 issued*
1990	Work on draft standards (ENVs) started
1992	Publication of ENV Eurocodes commenced
1998	Conversion of ENVs to ENs initiated
2004	*Directive on Public Works contracts, Public Supply contracts and Public Service contracts issued*
2006	Publication of ENs completed
2010	Full EN implementation; conflicting National Standards withdrawn
2020	Revised Structural Eurocodes published

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European Standards

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Three official European Standards Organisations undertake development of European Standards:

CEN (Comité Européen de Normalisation / European Committee for Standardisation)
All sectors except electrotechnology and telecommunication

CENELEC (Comité Européen de Normalisation Electrotechnique / European Committee for Electrotechnical Standardisation)
Electrotechnical standards

ETSI (European Telecommunications Standards Institute)
Telecommunications and some aspects of broadcasting

CEN is responsible for engineering standards, and operates using Technical Committees: CEN/TC250 controls the Structural Eurocodes.

CEN and the Structural Eurocodes

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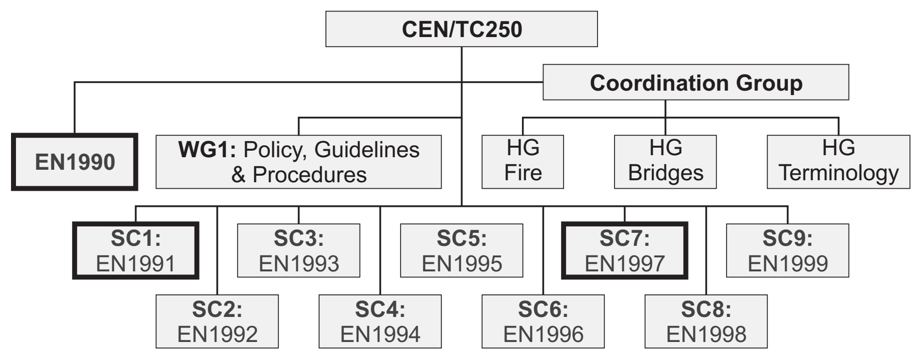

http://eurocodes.jrc.ec.europa.eu

EN1990 Basis of structural design
EN1991 Actions on structures
EN1992 Design of concrete structures
EN1993 Design of steel structures
EN1994 Design of composite steel and concrete structures
EN1995 Design of timber structures
EN1996 Design of masonry structures
EN1997 Geotechnical design
EN1998 Design of structures for earthquake resistance
EN1999 Design of aluminium structures

Maintenance of Structural Eurocodes

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The Structural Eurocodes are ‘living documents’ and hence are subject to maintenance.

Short, medium and long term cycles commence with the publication of a standard.

EC7 is currently undergoing a modified form of medium term maintenance, and a new edition is planned for publication in 2020.

Significant technical change to EC7 is many years in the future.

Publication of a Eurocode part

Short term (1 year)

Urgent matters of health and safety
Correction of technical and editorial mistakes

Corrigenda

Medium term (5 years)

Essential technical improvements
Essential editorial improvements
Resolution of interpretation questions
Requests from industry and public authorities

New edition of Eurocode or **Amendment**

Current revision period

Long term - **Further Development**

New generation of Eurocodes

Fundamental design requirements

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The Structural Eurocodes impose four fundamental requirements on designs:

Serviceability: during its intended life, and with appropriate degrees of reliability and in an economic way, the structure will remain fit for its intended use;

Safety: the structure will sustain all actions and influences likely to occur during construction and use;

Robustness: the structure will not be damaged by events such as explosion, impact or consequences of human errors, to an extent that is disproportionate to the original cause;

Fire: structural resistance shall be adequate for the required period of time.

These apply to rock engineering designs, and designers are required to demonstrate they have been satisfied

Note also that these requirements introduce the need for Quality Assurance during design, implementation, use and maintenance.

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The requirements are embodied in the use and definition of limit states:

For each geotechnical design situation it shall be verified that no relevant limit state... is exceeded.

[EN1997 §2.1(1)P]

Ultimate limit state

“The limit states that concern... the safety of people and/or the safety of the structure”

[EN1990 §3.3(1)P]

Servicability limit state

“The limit states that concern the functioning of the structure... under normal use”

[EN1990 §3.4(1)P]

‘Intended life’ has to be defined and taken into account:

[it is assumed that] the structure will be adequately maintained to ensure its safety and serviceability for the designed service life;

[EN1997 §1.3(2)]

...any significant deterioration in ground material properties that may occur during the lifetime of the structure

[EN1997 §2.4.3(5)]

When selecting the design situations, consideration shall be given to... all anticipated circumstances during the design life of the structure

[EN1997 §8.3(1)P]

Reliability based design

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The use of Factors of Safety (on either load or strength) in structural design was generally adequate until the early 20th Century.

Aircraft design in particular demanded a new approach, requiring designers to:

“*…produce evidence that the probable rate of accidents likely to cause injury to personnel arising from structural failure is not more than once in ‘x’ thousands of hours of flying.*” (Tye 1944)

Tye’s paper bears the provocative title

“Factors of safety – or of habit?”

Tye outlined the principal criteria for applying this philosophy:

Development of **clear definitions of failure**

Establishment of **acceptable failure rates**

Collection of **substantial data** relating to loading, material properties and structural behaviour

Structural engineers embraced this, starting in the late 1940s and leading to today’s structural design codes.

Fundamental representation of RBD

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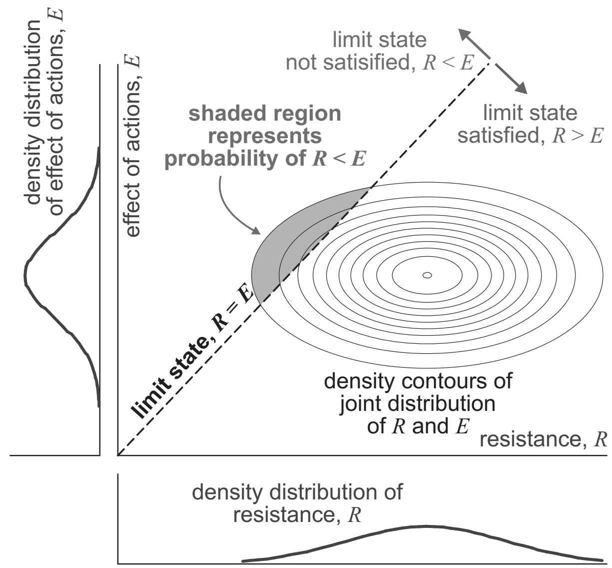
RBD assumes random variation for both load and strength.

EN 1990 generalises 'load' to **effect of actions**, E, and 'strength' to **resistance**, R.

The definition of a **limit state** is $R = E$.

Factor of safety is replaced with $\mathrm{P}(R < E)$.

Limit states may be **ultimate** (i.e. collapse) or **serviceability** (safe but unacceptable behaviour)



Acceptable failure rates

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EN 1990 specifies acceptable failure rates in terms of

consequence of attaining the ultimate limit state

for particular time periods.

These are based on societal acceptance of **structural collapse**.

A critical question for rock engineering is, what failure rates are acceptable?

Consequence of attaining the ultimate limit state	Minimum values of P_f in terms of reference period	
	1 year	50 year
High consequence for loss of human life, or economic, social or environmental consequences very great	1×10^{-7}	1×10^{-5}
Medium consequence for loss of human life, economic, social or environmental consequences considerable	1.5×10^{-6}	7×10^{-5}
Low consequence for loss of human life, and economic, social or environmental consequences small or negligible	1.5×10^{-5}	5×10^{-4}

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A simplified design approach: partial factors

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The position on the limit state line with greatest probability of occurrence is called the *design point*.

R_d and E_d can be given in terms of single values that *characterise* R and E.

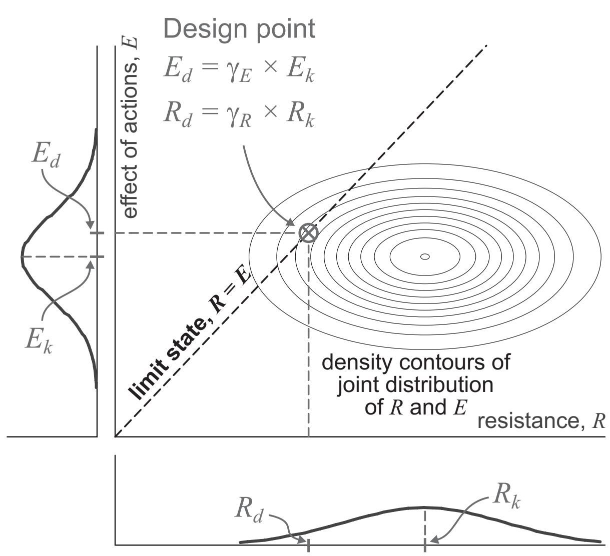
Partial factors are specific to

form of structure

material variability

target failure rate

definition of characteristic value



Eurocode 7 and rock engineering

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Initial development of the *structural Eurocodes* began in 1974 with

Models for International Codes for Design,

a project undertaken by an international consortium of various *structural engineering organisations*.

These codes adopted the recently-developed principles of *probabilistic limit state design for structural engineering*.

Initial development of *Eurocode 7* began in 1980, with work by ISSMFE on behalf of CEC: the roots of EC7 are firmly in European design codes for foundations on soils which were *not based on probabilistic limit state design principles*.

It also seems that there was *no formal input by either ISRM, IAEG or any other group with interests in rock engineering.*

EC7 is currently weak with regard to rock mechanics theory and rock engineering practice: this history indicates why this may be so.

Current rock engineering practice and EC7

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Uniquely in the development of engineering design, rock engineering has generally not considered RBD. Implementation of RBD poses many questions:

What are the definitions of limit states?

What failure rates are acceptable?

Can we obtain sufficient data, and if not, what are the alternatives?

Can partial factors be developed for rock engineering structures, or should other approaches be used?

The observational approach is central to rock engineering, so how can this be defined in terms of RBD?

During the current revision process these and other key questions are being considered.

Revisions have to be introduced within the framework of the Structural Eurocode suite, in particular the concept of Limit State Design.

Eurocode 7 will increase in importance for rock engineering.

It seems that RBD will become the future design practice for rock engineering.

Work is needed to both revise EC7 and develop rock engineering practice so that they become coherent.

The New Edition

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The current structure of EC7 is confused, and makes use of the Code difficult: *users need more than ten fingers!*

The structure of the New Edition will be:

Part 1: General Rules

Part 2: Ground Investigation

Part 3: Geotechnical Constructions *(sections for each major form of construction, e.g. shallow foundations, deep foundations, slopes, retaining structures)*

As far as possible, all Parts will be written to refer to a general material: 'ground'.

Within the Eurocode suite, 'Principles' and 'Application Rules' are unique to EC7. A need for coherency across the Structural Eurocodes means they will be replaced with this terminology:

'shall': this is ***required***

'should': this is ***recommended***

'may': this is ***permitted***

'can': the ***possibility*** of using this is recognised

Great care will be needed fit current rock engineering practice into this scheme.

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The revision process

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During 2011-2015, CEN/TC250/SC7 used a number of Evolution Groups to identify the necessary revisions.

For 2015-2020 CEN is funding a major revision effort, with a structure involving Project Teams, Working Groups and Task Groups.

The PTs comprise experts under contract to CEN, who will write the revised version. The WGs and TGs are volunteers, supporting the PTs.