OVERVIEW OF CODES FOR DESIGN AND ACTIONS ON STRUCTURES

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European Erasmus Mundus Master Course
Sustainable Constructions under Natural Hazards and Catastrophic Events
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SYLLABUS

1. Overview of codes for design and actions on structures

- Historical codes
- Action on structures according previous valid codes
- Design according to Eurocodes.

The professional engineer should always remember that codes and standards do not replace well founded engineering, good judgment and experience. The codes should not be used as a checklist of work, but as a guideline of the structure's minimum requirements. An engineer needs to be fully aware of the intent of the codes and the basis of its requirements and not blindly follow what is written in the code without a full understanding of good solid engineering requirements, as well as specific structure requirements, for the project being designed.

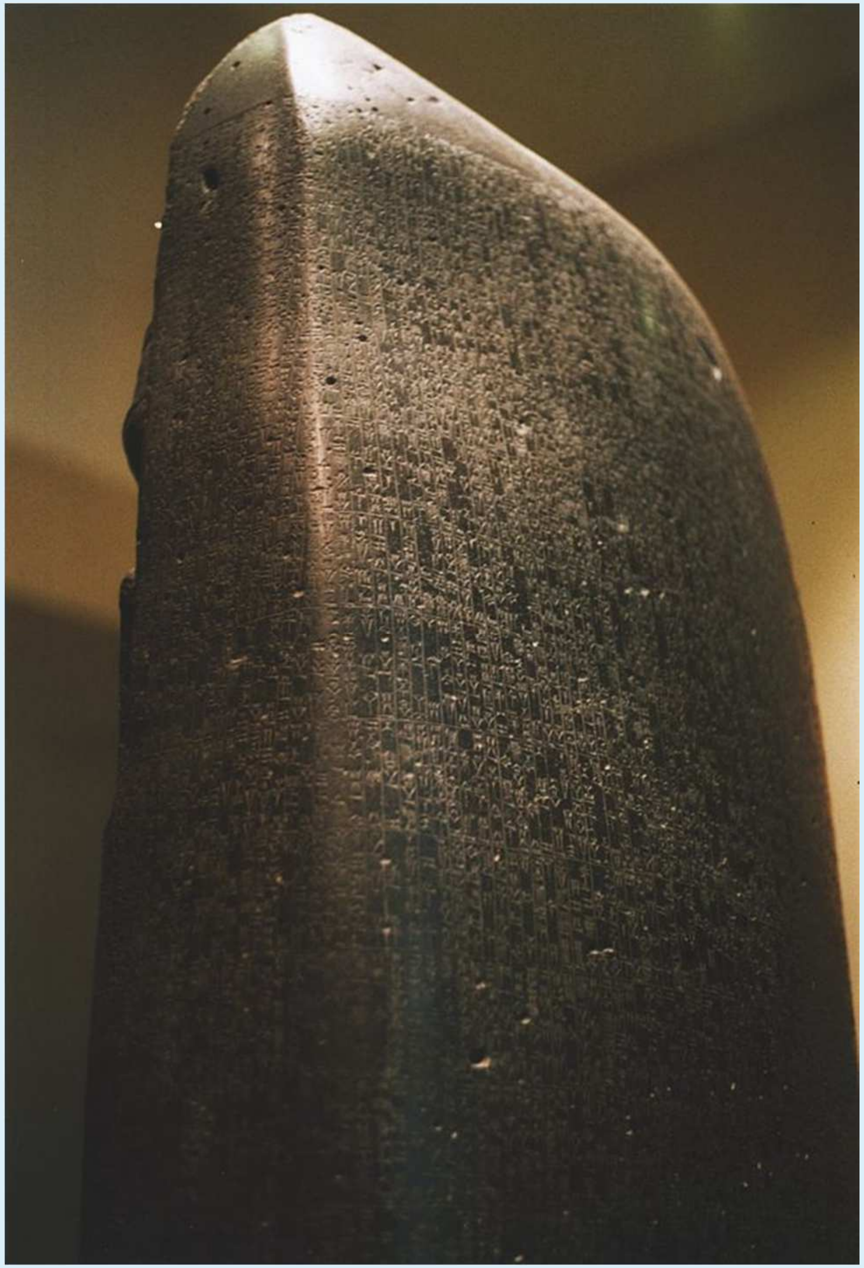
CODE OF HAMMURABI

The Code of Hammurabi is a well-preserved ancient law code, created about 1760 BC in ancient Babylon.

It was enacted by the sixth Babylonian king, Hammurabi.

Only one example of the Code survives today, inscribed on a basalt stone stele.

The text has been broken down by translators into 282 laws, but this division is arbitrary



CODE OF HAMMURABI

If a builder build a house for a man and do not make its construction firm, and the house which he has built collapse and cause the death of the owner of the house, that builder shall be put to death.

If it cause the death of a son of the owner of the house, they shall put to death a son of that builder.

If it cause the death of a slave of the owner of the house, he shall give to the owner of the house a slave of equal value.

If it destroy property, he shall restore whatever it destroyed, and because he did not make the house which he built firm and it collapsed, he shall rebuild the house which collapsed at his own expense.

If a builder build a house for a man and do not make its construction meet the requirements and a wall fall in, that builder shall strengthen that wall at his own expense.

BUILDING CODES

The restrictions encountered in building design are imposed by legal regulations

The most important ones for structural engineers are building codes, which represent a set of regulations regarding:

- principles of structural design
- guidance in evaluation of loads on structures
- specific design provisions for different type of structures (steel structures, reinforced concrete structures, foundations, etc.) and building components (electrical system, HVAC, plumbing, etc.)

In general, building-code requirements are the minimum needed for public protection.

FORMS OF BUILDING CODES

Codes can often be classified as specifications type or performance type

Specifications type codes:

- names specific materials for specific uses and specifies minimum or maximum dimensions,

Performance type codes:

- Specifies required performance of a construction but leaves materials, methods, and dimensions for the designers to choose.

Most codes are rather a mixture of specifications and performance type. The reason for this is that insufficient information is currently available for preparation of an entire enforceable performance code.

HISTORY OF SEISMIC DESIGN CODES

First attempts to introduce seismic design provisions in building codes date back to the end of the 19th century – beginning of the 20th century

Reason – major earthquakes that occurred in

- 1855, Edo, Japan
- 1891, Mino-Awari, Japan
- 1923, Kanto, Japan
- 1906, San Francisco, USA
- 1908, Messina, Italy

HISTORY OF SEISMIC DESIGN CODES

Earthquake engineering started at the end of the 19th century when some European engineers suggested designing structures with a few percent of the weight of the structure as the horizontal load:
F=CW

This idea of seismic design was taken up and developed in Japan at the beginning of the 20th century. In 1914, Sano, a Japanese engineer, developed a quasi-dynamic theory.

On April 18, 1906 a major earthquake struck San Francisco, followed by a wide-spread fire. Although engineers learned explicit lessons from the 1906 earthquake

HISTORY OF SEISMIC DESIGN CODES

June 28, 1925 – Santa Barbara (California, USA) earthquake

- Increased interest in earthquake engineering
- 1925: City Council passed a new building code with a clause requiring buildings to be designed to withstand horizontal forces produced by either earthquakes or wind
- 1927: shaking table built at Stanford
- 30s: Richter devised a numerical scale for grading
- instrumentally recorded earthquakes the local magnitude scale
- 1927: Uniform Building Code (UBC) – lateral forces determined as ~10% of the sum of permanent and live loads

HISTORY OF SEISMIC DESIGN CODES

March 10, 1933 –Long Beach (California, SUA) earthquake

- Considerable damage
- First strong ground motions
- Development of the concept of response spectra: Maurice Biot. The concept of response spectra was not used in a specific way in building codes until 1952.

HISTORY OF SEISMIC DESIGN CODES

1933-1959:

- 1943: Los Angeles Building Code (LABC) – the design requirements of a constant lateral force coefficient – inadequate. Seismic coefficient that was taking into account building flexibility associated with number of stories was introduced.
- 1952: "Lateral Forces of Earthquake and Wind" – period of vibration T of the building was introduced as a means of determining the base shear coefficient C
- 1957: To consider the inherent ductility and energy dissipation capacities of different structures, a coefficient K was introduced in the base shear equation V=KCW, where K values were specified for four types of building construction

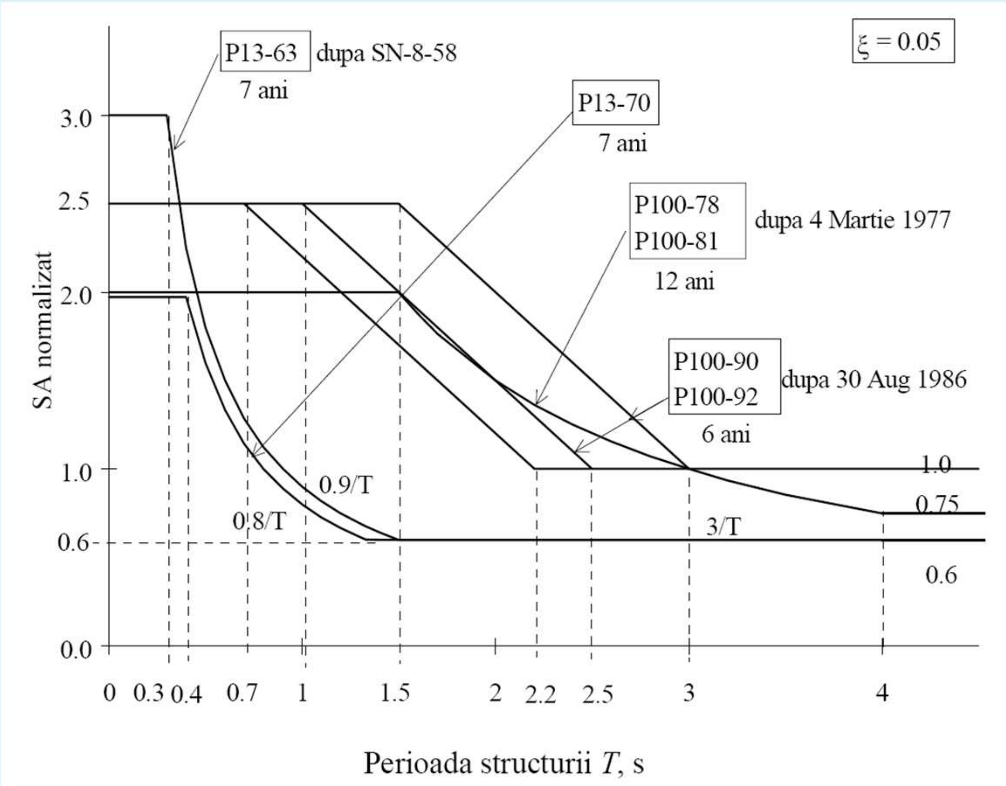
HISTORY OF SEISMIC DESIGN CODES IN ROMANIA

The first Romanian seismic resistant design code was developed in 1954.

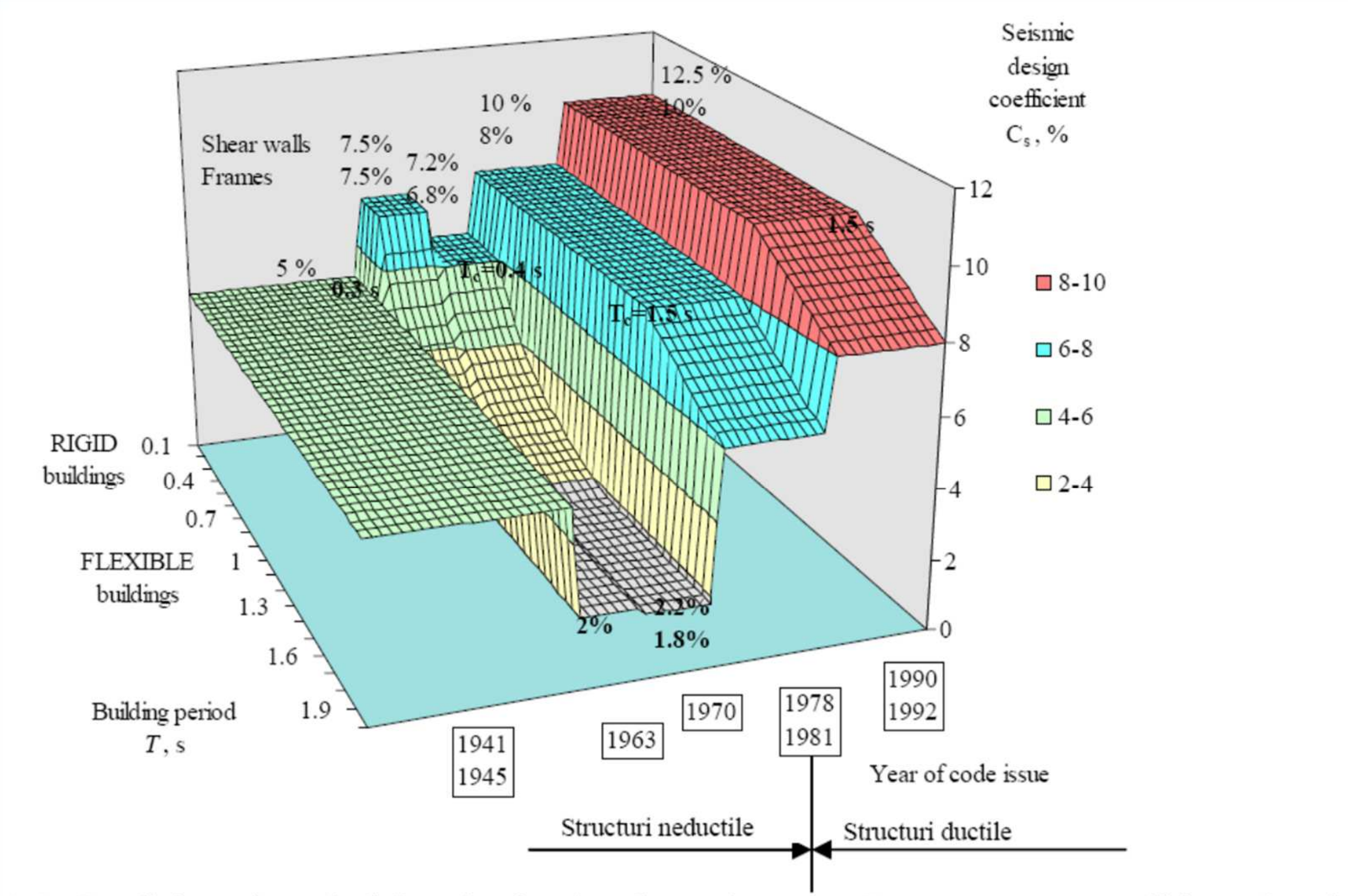
In 1963 this pioneering work was converted by the State Committee for Constructions, Architecture and Town Planning into the P13-63 code

HISTORY OF SEISMIC DESIGN CODES IN ROMANIA

Normalised elastic response spectra for Bucharest – evolution in seismic design codes



HISTORY OF SEISMIC DESIGN CODES IN ROMANIA



4.4. Coeficientul total al forței seismice de proiectare, C_s pentru construcții în cadre și cu pereți structurali din București, în perioada 1941-2000 (Lungu, Demetriu).

THE EUROCODES

European continent was traditionally divided in many countries, each with its own building design code $\Rightarrow$ firms were constrained to design/fabricate/construct for their own country market

With the advent of the European Union, it has developed a single market through a standardised system of laws which apply in all member states, guaranteeing the freedom of movement of people, goods, services and capital

The objective of the European Commission is for “the Eurocodes to establish a set of common technical rules for the design of buildings and civil engineering works which will ultimately replace the differing rules in the various Member States”.

WHAT ARE THE EUROCODES?

The Eurocodes are a set of European Standards (EN) for the design of buildings and other civil engineering works and construction products

The Eurocodes embody National experience and research output together with the expertise of CEN Technical Committee 250 (CEN/TC250) and of International Technical and Scientific Organisations and represent a "world-class standard for structural design".

Publication of the Eurocodes was completed in 2007. Following CEN rules, the Eurocodes can be used in parallel with National Standards until 2010, when all conflicting National Standards should be withdrawn.

WHAT ARE THE EUROCODES?

The Eurocodes cover in a comprehensive manner:

- all principal construction materials (concrete, steel, timber, masonry and aluminium),
- all major fields of structural engineering (basis of structural design, loading, fire, geotechnics, earthquake, etc.) and
- a wide range of types of structures and products (buildings, bridges, towers and masts, silos, etc).

The verification procedure in the Eurocodes is based on the limit state concept used in conjunction with partial safety factors. The Eurocodes allow also for design based on probabilistic methods as well as for design assisted by testing, and provide guidance for the use of these methods.

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THE EUROCODES SUITE

The Eurocodes suite is made up by 10 European Standards for structural design

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

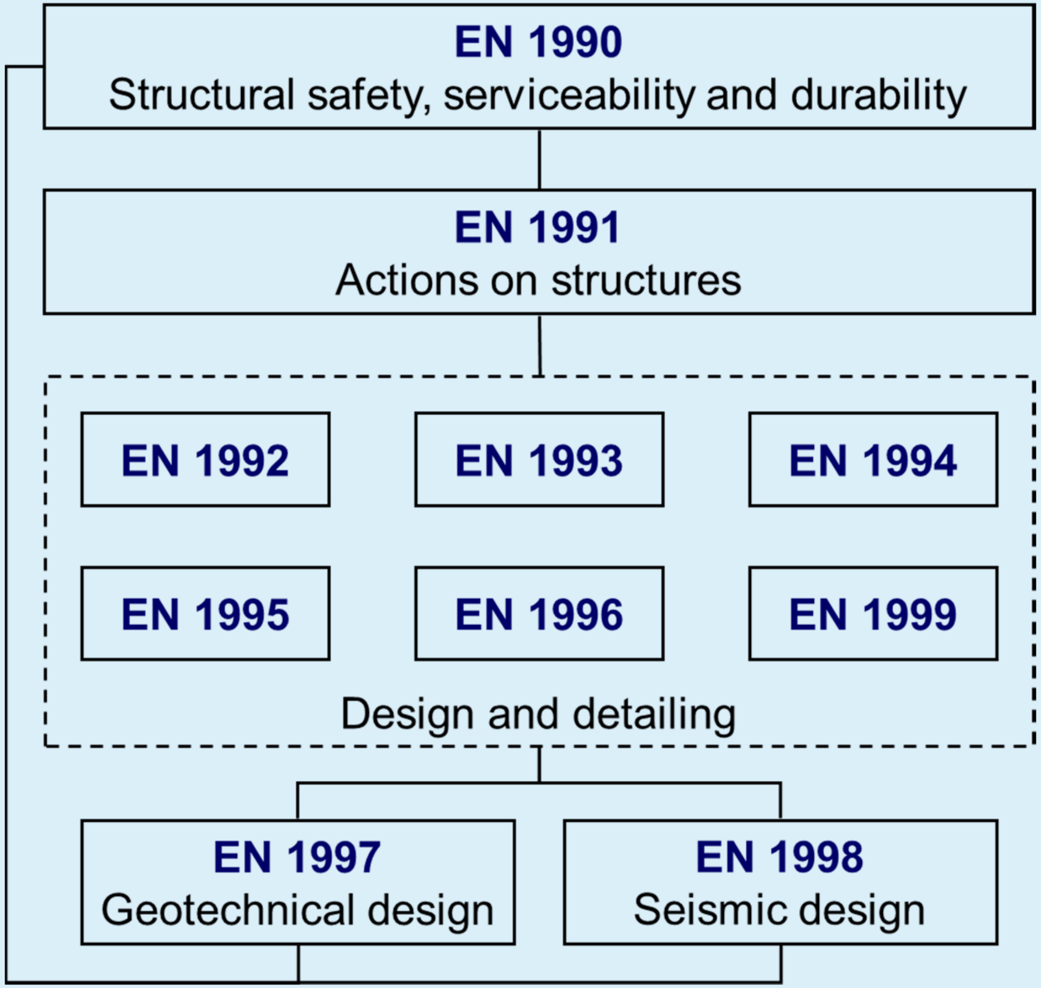
EN 1996 Eurocode 6: Design of masonry structures

EN 1997 Eurocode 7: Geotechnical design

EN 1998 Eurocode 8: Design of structures for earthquake resistance

EN 1999 Eurocode 9: Design of aluminium structures

LINKS BETWEEN THE EUROCODES



EN EUROCODE PARTS AND PACKAGES

Each of the codes (except EN 1990) is divided into a number of Parts covering specific aspects of the subject

In total there are 58 EN Eurocode parts distributed in the ten Eurocodes (EN 1990 – 1999)

All of the EN Eurocodes relating to materials have a Part 1-1 which covers the design of buildings and other civil engineering structures and a Part 1-2 for fire design

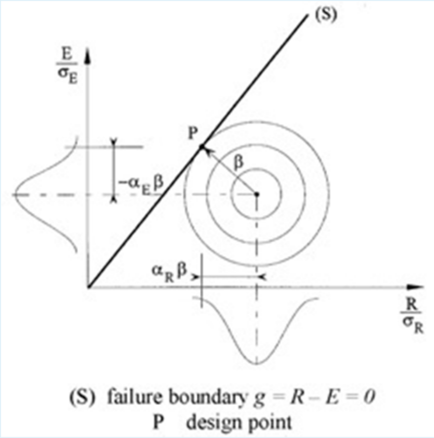
The EN Eurocode Parts have been grouped into Packages, each of which must be published before the implementation of that set of EN Eurocodes may begin

EN 1990: BASIS OF STRUCTURAL DESIGN

EN 1990 establishes Principles and Requirements for the safety, serviceability and durability of structures, describes the basis for their design and verification and gives guidelines for related aspects of structural reliability

EN 1990 is intended to be used in conjunction with EN 1991 to EN 1999 for the structural design of buildings and other civil engineering works, including geotechnical aspects, structural fire design, situations involving earthquakes, execution and temporary structures. For the design of special construction works (e.g. nuclear installations, dams, etc.), other provisions than those in EN 1990 to EN 1999 might be necessary.

EN 1990: BASIS OF STRUCTURAL DESIGN



EN 1990 is applicable for the design of structures where other materials or other actions outside the scope of EN 1991 to EN 1999 are involved.

EN 1990 is applicable for the structural appraisal of existing construction, in developing the design of repairs and alterations or in assessing change of use.

EN 1990 may be used, when relevant, as a guidance document for the design of structures outside the scope of the Eurocodes EN 1991 to EN 1999, for:

- assessing other actions and their combinations;
- modelling material and structural behaviour;
- assessing numerical values of the reliability format.

EN 1991: ACTIONS ON STRUCTURES

EN 1991 (Eurocode 1) provides comprehensive information on all actions that should normally be considered in the design of buildings and other civil engineering works, including some geotechnical aspects.

EN 1991 is intended to be used in conjunction with EN 1992 to EN 1999 for the structural design of buildings and other civil engineering works.

EN 1991 is divided into four main parts:

- Part 1: General actions
- Part 2: Traffic loads on bridges
- Part 3: Actions induced by cranes and machinery
- Part 4: Silos and tanks

EN 1991: ACTIONS ON STRUCTURES

EN 1991-1-1:2002	Eurocode 1: Actions on structures - Part 1-1: General actions - Densities, self-weight, imposed loads for buildings
EN 1991-1-2:2002	Eurocode 1: Actions on structures - Part 1-2: General actions - Actions on structures exposed to fire
EN 1991-1-3:2003	Eurocode 1: Actions on structures - Part 1-3: General actions - Snow loads
EN 1991-1-4:2005	Eurocode 1: Actions on structures - Part 1-4: General actions - Wind actions
EN 1991-1-5:2003	Eurocode 1: Actions on structures - Part 1-5: General actions - Thermal actions
EN 1991-1-6:2005	Eurocode 1: Actions on structures - Part 1-6: General actions - Actions during execution
EN 1991-1-7:2006	Eurocode 1: Actions on structures - Part 1-7: General actions - Accidental actions
EN 1991-2:2003	Eurocode 1: Actions on structures - Part 2: Traffic loads on bridges
EN 1991-3:2006	Eurocode 1: Actions on structures - Part 3: Actions induced by cranes and machinery
EN 1991-4: 2006	Eurocode 1: Actions on structures - Part 4: Silos and tanks

EN 1992: DESIGN OF CONCRETE STRUCTURES

EN 1992 (Eurocode 2) applies to the design of buildings and other civil engineering works in plain, reinforced and prestressed concrete.

Eurocode 2 is concerned with the requirements for resistance, serviceability, durability and fire resistance of concrete structures.

- Part 1-1 gives a general basis for the design of structures in plain, reinforced and prestressed concrete
- Part 1-2 deals with the design of concrete structures for the accidental situation of fire exposure
- Part 2 gives a general basis for the design and detailing of bridges in reinforced and prestressed concrete
- Part 3 covers additional rules for the design of concrete structures for the containment of liquids or granular solids and other liquid retaining structures

EN 1992: DESIGN OF CONCRETE STRUCTURES

EN 1992-1-1:2004	Eurocode 2: Design of concrete structures - Part 1-1: General rules and rules for buildings
EN 1992-1-2:2004	Eurocode 2: Design of concrete structures - Part 1-2: General rules - Structural fire design
EN 1992-2:2005	Eurocode 2: Design of concrete structures - Part 2: Concrete bridges - Design and detailing rules
EN 1992-3:2006	Eurocode 2: Design of concrete structures - Part 3: Liquid retaining and containment structures

EN 1993: DESIGN OF STEEL STRUCTURES

EN 1993 (Eurocode 3) applies to the design of buildings and other civil engineering works in steel.

EN 1993 is concerned with requirements for resistance, serviceability, durability and fire resistance of steel structures.

EN Eurocode 3 is wider in scope than most of the other design EN Eurocodes due to the diversity of steel structures, the need to cover both bolted and welded joints and the possible slenderness of construction.

EN 1993 has 20 parts covering common rules, fire design, bridges, buildings, tanks, silos, pipelined piling, crane supported structures, towers and masts, chimneys etc.

EN 1993: DESIGN OF STEEL STRUCTURES

EN 1993-1-1:2005	Eurocode 3: Design of steel structures - Part 1-1: General rules and rules for buildings
EN 1993-1-2:2005	Eurocode 3: Design of steel structures - Part 1-2: General rules - Structural fire design
EN 1993-1-3:2006	Eurocode 3: Design of steel structures - Part 1-3: General rules - Supplementary rules for cold-formed members and sheeting
EN 1993-1-4:2006	Eurocode 3: Design of steel structures - Part 1-4: General rules - Supplementary rules for stainless steels
EN 1993-1-5:2006	Eurocode 3: Design of steel structures - Part 1-5: General rules - Plated structural elements
EN 1993-1-6:2007	Eurocode 3: Design of steel structures - Part 1-6: Strength and stability of shell structures
EN 1993-1-7:2007	Eurocode 3: Design of steel structures - Part 1-7: Strength and stability of planar plated structures subject to out of plane loading
EN 1993-1-8:2005	Eurocode 3: Design of steel structures - Part 1-8: Design of joints
EN 1993-1-9:2005	Eurocode 3: Design of steel structures - Part 1-9: Fatigue

EN 1993: DESIGN OF STEEL STRUCTURES

EN 1993-1-10:2005	Eurocode 3: Design of steel structures - Part 1-10: Material toughness and through-thickness properties
EN 1993-1-11:2006	Eurocode 3: Design of steel structures - Part 1-11: Design of structures with tension components
EN 1993-1-12:2007	Eurocode 3: Design of steel structures - Part 1-12: General - High strength steels
EN 1993-2:2006	Eurocode 3: Design of steel structures - Part 2: Steel bridges
EN 1993-3-1:2006	Eurocode 3: Design of steel structures - Part 3-1: Towers, masts and chimneys – Towers and masts
EN 1993-3-2:2006	Eurocode 3: Design of steel structures - Part 3-2: Towers, masts and chimneys – Chimneys
EN 1993-4-1:2007	Eurocode 3: Design of steel structures - Part 4-1: Silos
EN 1993-4-2:2007	Eurocode 3: Design of steel structures - Part 4-2: Tanks
EN 1993-4-3:2007	Eurocode 3: Design of steel structures - Part 4-3: Pipelines
EN 1993-5:2007	Eurocode 3: Design of steel structures - Part 5: Piling
EN 1993-6:2007	Eurocode 3: Design of steel structures - Part 6: Crane supporting structures

EN 1994: DESIGN OF COMPOSITE STEEL AND CONCRETE STRUCTURES

EN 1994 (Eurocode 4) applies to the design of composite structures and members for buildings and other civil engineering works

EN 1994 is concerned with requirements for resistance, serviceability, durability and fire resistance of composite structures.

EN 1994 is intended to be used in conjunction with:

- EN 1992: Eurocode 2 - Design of concrete structures and
- EN 1993: Eurocode 3 - Design of steel structures

EN 1994: DESIGN OF COMPOSITE STEEL AND CONCRETE STRUCTURES

EN 1994-1-1:2004	Eurocode 4: Design of composite steel and concrete structures – Part 1-1: General rules and rules for buildings
EN 1994-1-2:2005	Eurocode 4: Design of composite steel and concrete structures – Part 1-2: General rules - Structural fire design
EN 1994-2:2005	Eurocode 4: Design of composite steel and concrete structures – Part 2: General rules and rules for bridges

EN 1995: DESIGN OF TIMBER STRUCTURES

EN 1995 (Eurocode 5) applies to the design of buildings and other civil engineering works in timber (solid timber, sawn, planed or in pole form, glued laminated timber or wood-based structural products) or wood-based panels jointed together with adhesives or mechanical fasteners

EN 1995-1-1:2004	Eurocode 5: Design of timber structures - Part 1-1: General - Common rules and rules for buildings
EN 1995-1-2:2004	Eurocode 5: Design of timber structures - Part 1-2: General - Structural fire design
EN 1995-2:2004	Eurocode 5: Design of timber structures - Part 2: Bridges

EN 1996: DESIGN OF MASONRY STRUCTURES

EN 1996 applies to the design of buildings and other civil engineering works in masonry.

The execution is covered to the extent that is necessary to indicate the quality of the construction materials and products that should be used and the standard of workmanship on site

EN 1996-1-1:2005	Eurocode 6: Design of masonry structures - Part 1-1: General rules for reinforced and unreinforced masonry structures
EN 1996-1-2:2005	Eurocode 6: Design of masonry structures - Part 1-2: General rules - Structural fire design
EN 1996-2:2006	Eurocode 6: Design of masonry structures - Part 2: Design considerations, selection of materials and execution of masonry
EN 1996-3:2006	Eurocode 6: Design of masonry structures - Part 3: Simplified calculation methods for unreinforced masonry structures

EN 1997: GEOTECHNICAL DESIGN

EN 1997 (Eurocode 7) applies to the geotechnical aspects of the design of buildings and other civil engineering works

Numerical values of actions on buildings and other civil engineering works to be taken into account in design are provided in EN 1991 for the various types of construction, whereas actions imposed by the ground, such as earth pressures and by ground water, shall be calculated according to the rules of EN 1997.

EN 1997-1:2004	Eurocode 7: Geotechnical design - Part 1: General rules
EN 1997-2:2007	Eurocode 7: Geotechnical design - Part 2: Ground investigation and testing

EN 1998: DESIGN OF STRUCTURES FOR EARTHQUAKE RESISTANCE

EN 1998 Eurocode 8 applies to the design and construction of buildings and other civil engineering works in seismic regions.

Its purpose is to ensure that in the event of earthquakes

- human lives are protected;
- damage is limited;
- structures important for civil protection remain operational.

The random nature of the seismic events and the limited resources available to counter their effects are such as to make the attainment of these goals only partially possible and only measurable in probabilistic terms.

EN 1998: DESIGN OF STRUCTURES FOR EARTHQUAKE RESISTANCE

The extent of the protection that can be provided to different categories of buildings, which is only measurable in probabilistic terms, is a matter of optimal allocation of resources and is therefore expected to vary from country to country, depending on the relative importance of the seismic risk with respect to risks of other origin and on the global economic resources.

Special structures, such as nuclear power plants, offshore structures and large dams, are beyond the scope of EN 1998.

EN 1998: DESIGN OF STRUCTURES FOR EARTHQUAKE RESISTANCE

EN 1998 contains only those provisions that, in addition to the provisions of the other relevant EN Eurocodes, must be observed for the design of structures in seismic regions. It complements in this respect the other EN Eurocodes.

EN 1998-1:2004	Eurocode 8: Design of structures for earthquake resistance – Part 1: General rules, seismic actions and rules for buildings
EN 1998-2:2005	Eurocode 8: Design of structures for earthquake resistance – Part 2: Bridges
EN 1998-3:2005	Eurocode 8: Design of structures for earthquake resistance – Part 3: Assessment and retrofitting of buildings
EN 1998-4:2006	Eurocode 8: Design of structures for earthquake resistance – Part 4: Silos, tanks and pipelines
EN 1998-5:2004	Eurocode 8: Design of structures for earthquake resistance – Part 5: Foundations, retaining structures and geotechnical aspects
EN 1998-6:2005	Eurocode 8: Design of structures for earthquake resistance – Part 6: Towers, masts and chimneys

EN 1999: DESIGN OF ALUMINIUM STRUCTURES

EN 1999 Eurocode 9 applies to the design of buildings and other civil engineering and structural works in aluminium.

EN 1999 is concerned with requirements for resistance, serviceability, durability and fire resistance of aluminium structures.

EN 1999-1-1:2007	Eurocode 9: Design of aluminium structures - Part 1-1: General structural rules
EN 1999-1-2:2007	Eurocode 9: Design of aluminium structures - Part 1-2: Structural fire design
EN 1999-1-3:2007	Eurocode 9: Design of aluminium structures - Part 1-3: Structures susceptible to fatigue
EN 1999-1-4:2007	Eurocode 9: Design of aluminium structures - Part 1-4: Cold-formed structural sheeting
EN 1999-1-5:2007	Eurocode 9: Design of aluminium structures - Part 1-5: Shell structures

EU LEGISLATION FOR CONSTRUCTION WORKS AND PRODUCTS

The Construction Products aim is to breakdown artificial barriers to trade

According to the Construction Products Directive, construction products suitable for construction works need to satisfy the following six essential requirements as appropriate:

- <u>mechanical resistance and stability</u>
- <u>safety in case of a fire</u>
- hygiene, health and the environment
- <u>safety in use</u>
- protection against noise
- energy economy and heat retention

EU LEGISLATION FOR CONSTRUCTION WORKS AND PRODUCTS

The EN provide common design methods, expressed in a set of European standards:

- prove the compliance of building and civil engineering works or parts thereof with Essential Requirement
- express in technical terms , these Essential Requirements applicable to the works and parts thereof;

IMPLEMENTATION OF THE EUROCODES

When an EN Eurocode Part is made available by CEN (Date of Availability), National Authorities and National Standards Bodies should:

- translate the Eurocode Part in authorised national languages
- set the Nationally Determined Parameters to be applied on their territory
- publish the National Standard transposing the EN Eurocode Part and the National Annex
- adapt their National Provisions so that the EN Eurocode Part can be used on their territory
- promote training on the Eurocodes

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