Basis of Structural Design

Course 8

Design codes:

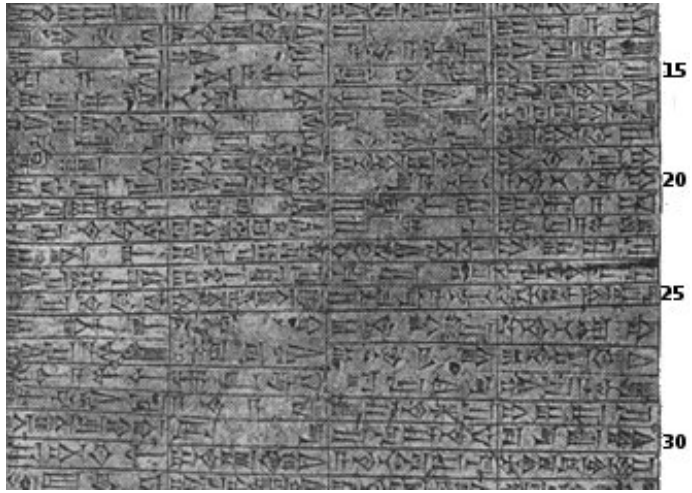
- Structural Eurocodes

- Current Romanian codes

Course notes are available for download at
https://www.ct.upt.ro/studenti/cursuri/stratan/bsd.htm

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. Originally, several stelae would have been displayed in temples around the empire.
- The text has been broken down by translators into 282 laws, but this division is arbitrary, since the original text contains no divisional markers



Code of Hammurabi (excerpt)

...

- § 228. If a builder build a house for a man and complete it, (that man) shall give him two shekels of silver per SAR of house as his wage.
- § 229. 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.
- § 230. If it cause the death of a son of the owner of the house, they shall put to death a son of that builder.
- § 231. 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.
- § 232. 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.
- § 233. 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

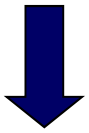
- Many of the restrictions encountered in building design are imposed by legal regulations
- The most important ones for structural engineers are building codes, which represent a set of regulations regarding:
  - principles of structural design
  - guidance in evaluation of loads on structures
  - specific 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.
- Often, however, architects and engineers must design more conservatively, to meet the client's needs, produce a more efficient building system, or take into account conditions not covered fully by code provisions.

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,
  - for example, "a brick wall may not be less than 40 cm thick".
- Performance type codes:
  - Specifies required performance of a construction but leaves materials, methods, and dimensions for the designers to choose.
  - Performance-type codes are generally preferred, because they give designers greater design freedom in meeting clients' needs, while satisfying the intent of the code.
- 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.

The Eurocodes: why?

- European continent was traditionally divided in many countries, each with its own building design code ⇒ 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 are produced by the Comité Européen de Normalisation (CEN).
- 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?

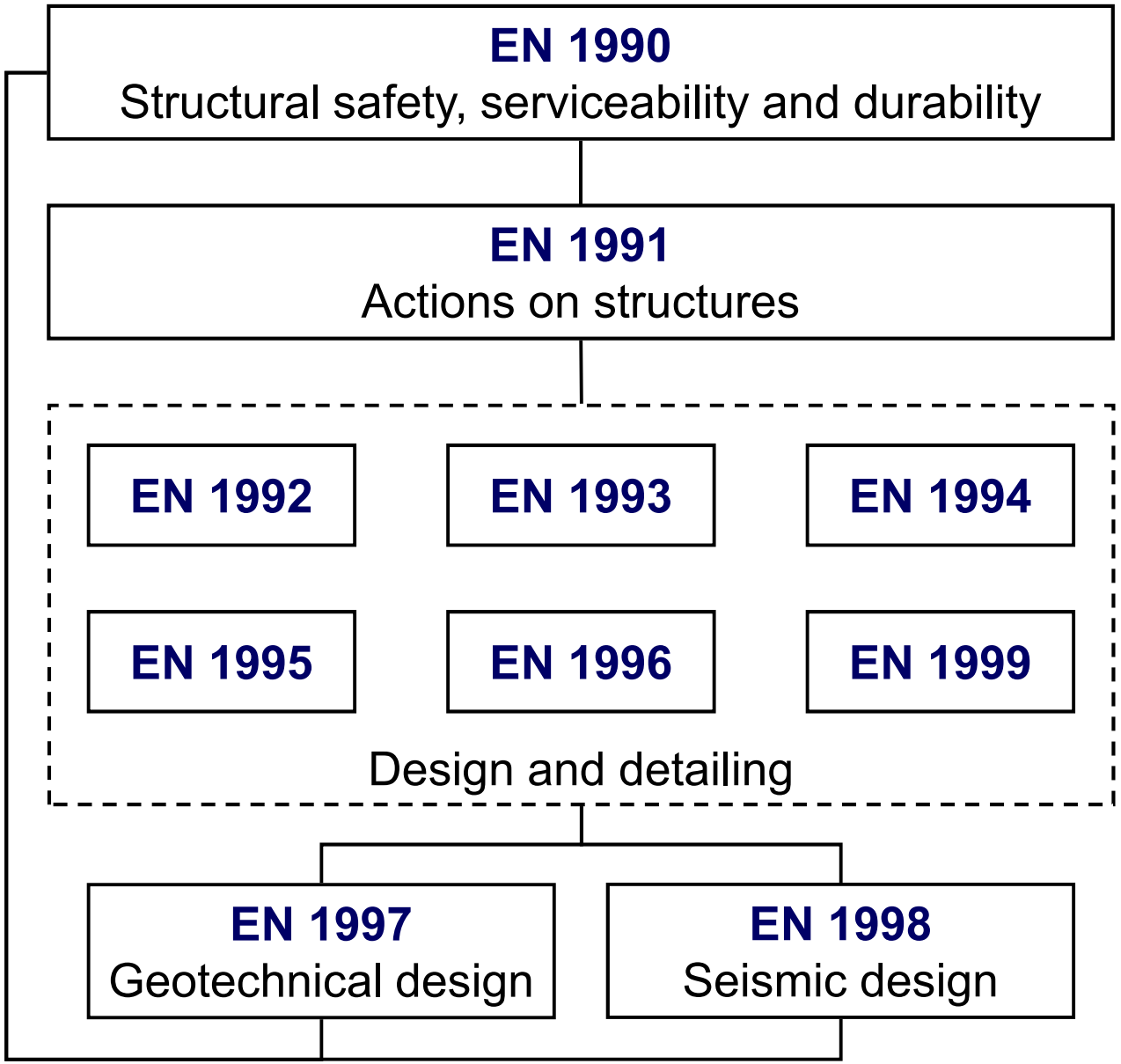
- The Eurocodes cover in a comprehensive manner:
  - all principal construction materials (concrete, steel, timber, masonry and aluminium),
  - all major fields of structural engineering (basis of structural design, loading, fire, geotechnics, earthquake, etc.) and
  - a wide range of types of structures 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.

The Eurocodes suite

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

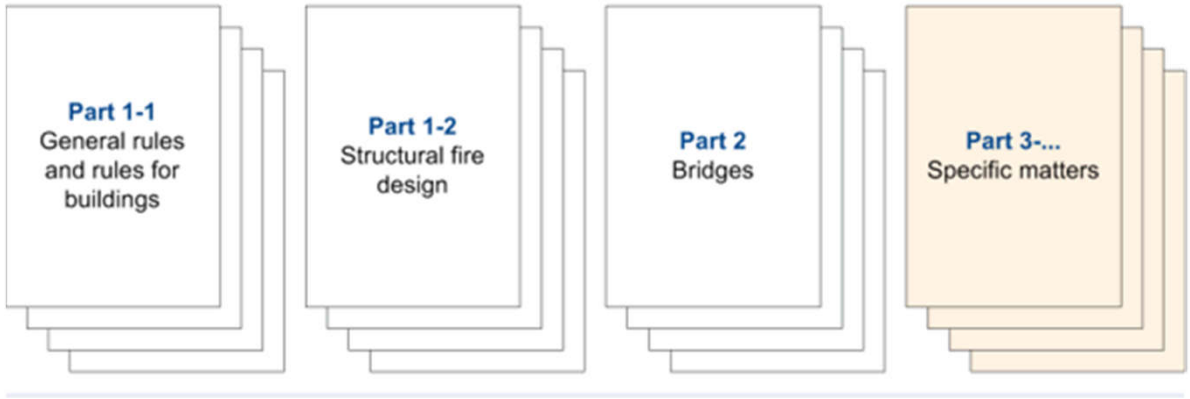
- **EN 1990 Eurocode: Basis of structural design**
- **EN 1991 Eurocode 1: Actions on structures**
- **EN 1992 Eurocode 2: Design of concrete structures**
- **EN 1993 Eurocode 3: Design of steel structures**
- **EN 1994 Eurocode 4: Design of composite steel and concrete structures**
- **EN 1995 Eurocode 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

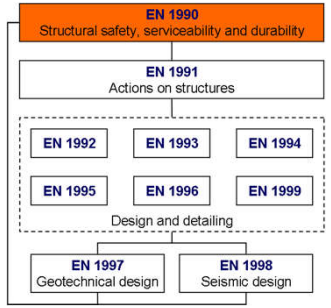
- Each of the codes (except EN 1990) is divided into a number of Parts covering specific aspects of the subject
- In total there are 58 EN Eurocode parts distributed in the ten Eurocodes (EN 1990 – 1999)
- All of the EN Eurocodes relating to materials have a Part 1-1 which covers the design of buildings and other civil engineering structures and a Part 1-2 for fire design



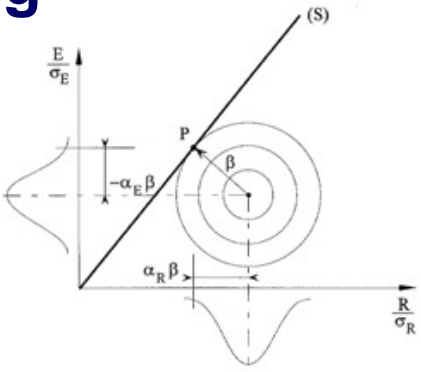
- The EN Eurocode Parts have been grouped into Packages, each of which must be published before the implementation of that set of EN Eurocodes may begin

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



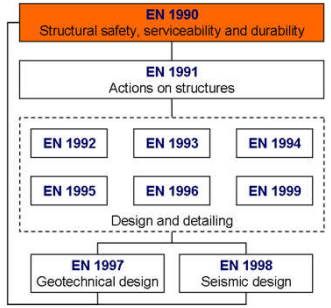
- EN 1990 is intended to be used in conjunction with EN 1991 to EN 1999 for the structural design of buildings and other civil engineering works, including geotechnical aspects, structural fire design, situations involving earthquakes, execution and temporary structures. For the design of special construction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

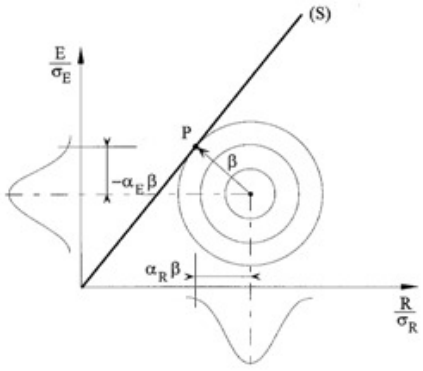


(S) failure boundary $g = R - E = 0$
P design point

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.

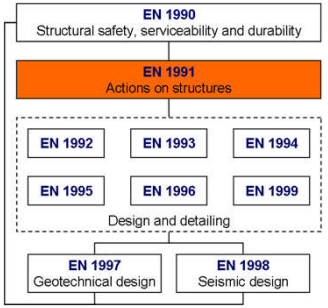


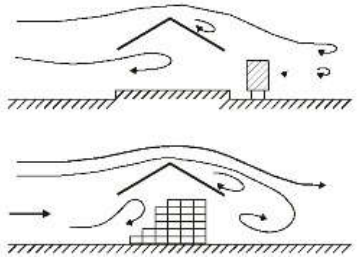


(S) failure boundary $g = R - E = 0$
P design point

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



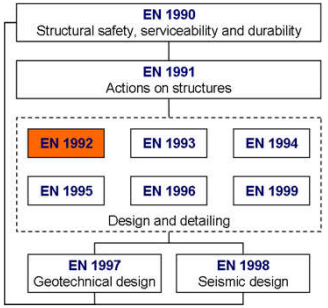


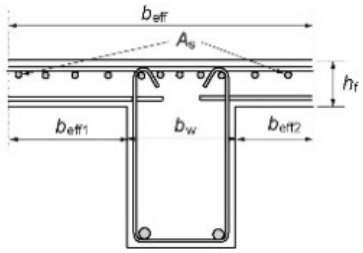
EN 1991: Actions on structures

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

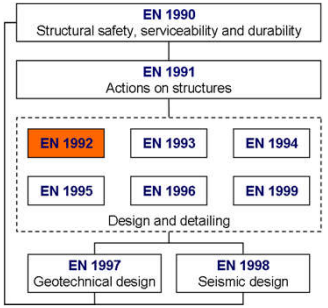
EN 1992: Design of concrete structures

- **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**

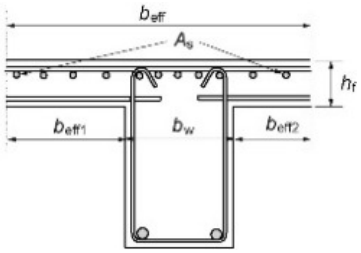




EN 1992: Design of concrete structures

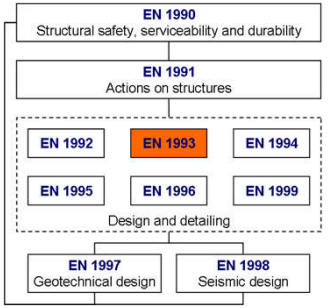


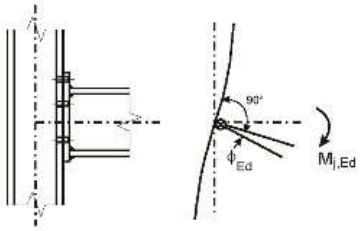
EN 1992-1-1:2004	**Eurocode 2: Design of concrete structures - Part 1-1: General rules and rules for buildings**
EN 1992-1-2:2004	**Eurocode 2: Design of concrete structures - Part 1-2: General rules - Structural fire design**
EN 1992-2:2005	**Eurocode 2: Design of concrete structures - Part 2: Concrete 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

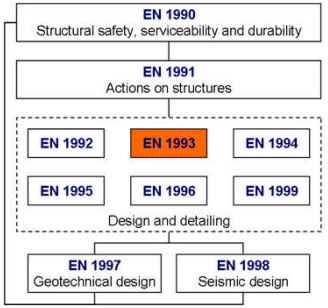
- EN 1993 (Eurocode 3) applies to the design of buildings and other civil engineering works in steel.
- EN 1993 is concerned with requirements for resistance, serviceability, durability and fire resistance of steel structures.
- EN Eurocode 3 is wider in scope than most of the other design EN Eurocodes 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.

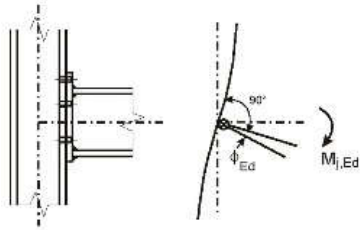




EN 1993: Design of steel structures

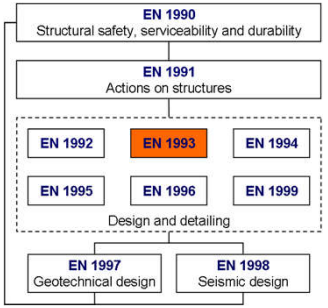
EN 1993-1-1:2005	Eurocode 3: Design of steel structures - Part 1-1: General rules and rules for buildings
EN 1993-1-2:2005	Eurocode 3: Design of steel structures - Part 1-2: General rules - Structural fire design
EN 1993-1-3:2006	Eurocode 3: Design of steel structures - Part 1-3: General rules - Supplementary 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

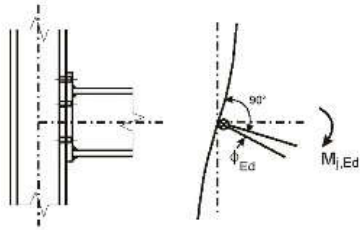




EN 1993: Design of steel structures

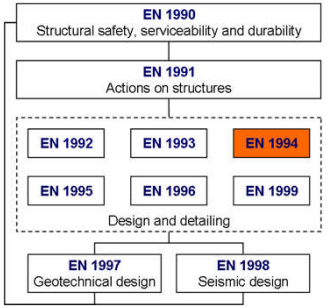
EN 1993-1-10:2005	Eurocode 3: Design of steel structures - Part 1-10: Material toughness and through-thickness properties
EN 1993-1-11:2006	Eurocode 3: Design of steel structures - Part 1-11: Design of structures with tension components
EN 1993-1-12:2007	Eurocode 3: Design of steel structures - Part 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



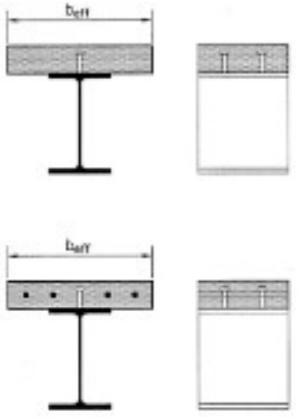


EN 1994: Design of composite steel and concrete structures

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

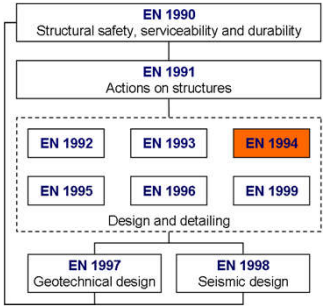


- EN 1994 is concerned with requirements for resistance, serviceability, durability and fire resistance of composite structures.

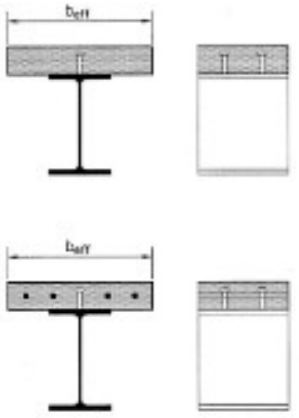


- EN 1994 is intended to be used in conjunction with:
  - EN 1992: Eurocode 2 - Design of concrete structures and
  - EN 1993: Eurocode 3 - Design of steel structures

EN 1994: Design of composite steel and concrete structures

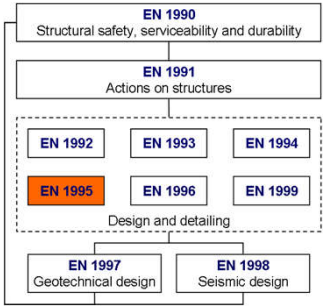


EN 1994-1-1:2004	**Eurocode 4: Design of composite steel and concrete structures – Part 1-1: General rules and rules for buildings**
EN 1994-1-2:2005	**Eurocode 4: Design of composite steel and concrete structures – Part 1-2: General rules - Structural fire design**
EN 1994-2:2005	**Eurocode 4: Design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

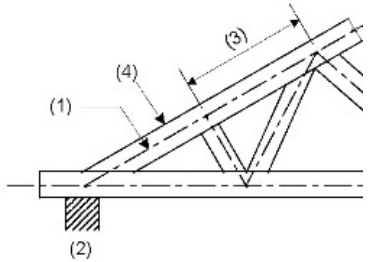


EN 1995: Design of timber structures

- **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**

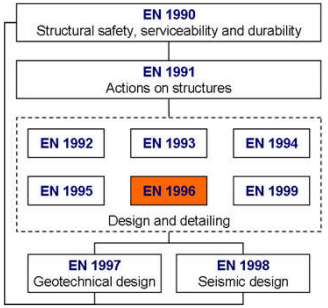


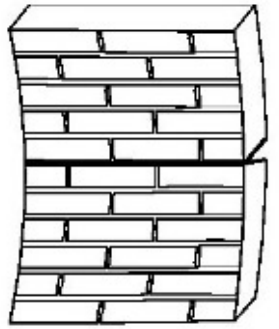
EN 1995-1-1:2004	Eurocode 5: Design of timber structures - Part 1-1: General - Common rules and rules for buildings
EN 1995-1-2:2004	Eurocode 5: Design of timber structures - Part 1-2: General - Structural fire design
EN 1995-2:2004	Eurocode 5: Design of timber structures - Part 2: Bridges



EN 1996: Design of masonry structures

- EN 1996 (Eurocode 6) applies to the design of buildings and other civil engineering works, or parts thereof, in unreinforced, reinforced, prestressed and confined 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 needed to comply with the assumptions made in the design rules.

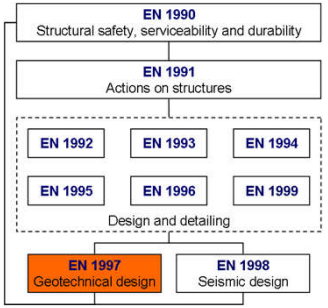


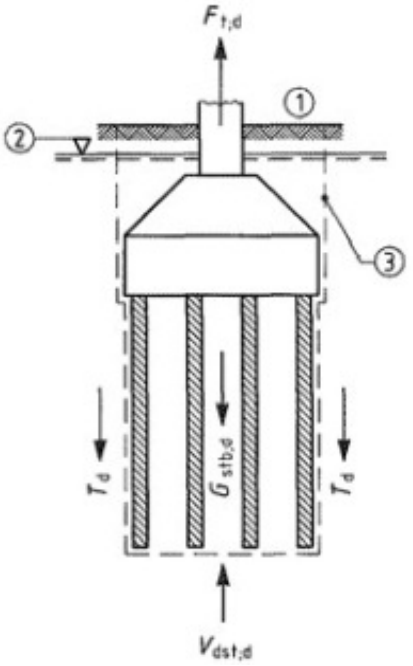


EN 1996-1-1:2005	Eurocode 6: Design of masonry structures - Part 1-1: General rules for reinforced and unreinforced masonry structures
EN 1996-1-2:2005	Eurocode 6: Design of masonry structures - Part 1-2: General rules - Structural fire design
EN 1996-2:2006	Eurocode 6: Design of masonry structures - 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.

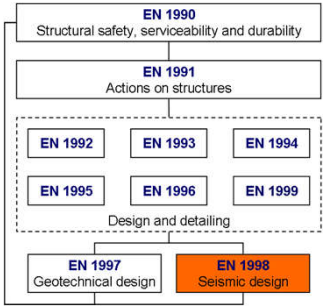


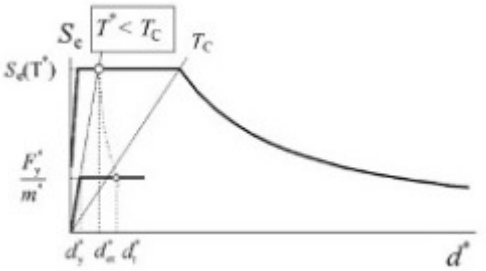


EN 1997-1:2004	Eurocode 7: Geotechnical design - Part 1: General rules
EN 1997-2:2007	Eurocode 7: Geotechnical design - Part 2: Ground investigation and testing

EN 1998: Design of structures for earthquake resistance

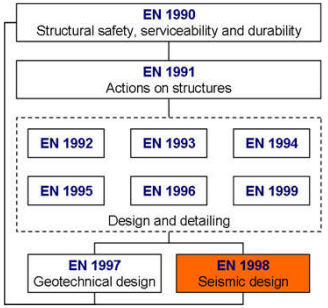
- EN 1998 Eurocode 8 applies to the design and construction of buildings and other civil engineering works in seismic regions.
- Its purpose is to ensure that in the event of earthquakes
  - human lives are protected;
  - damage is limited;
  - structures important for civil protection remain operational.
- 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.

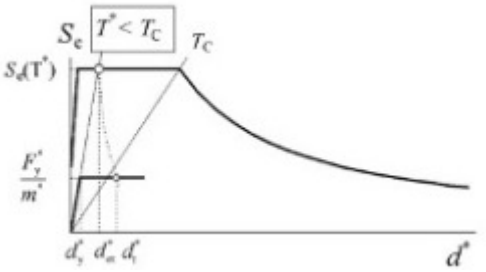




EN 1998: Design of structures for earthquake resistance

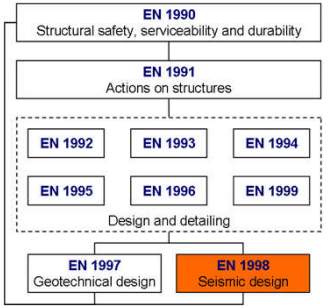
- The extent of the protection that can be provided to different categories of buildings, which is only measurable in probabilistic terms, is a matter of optimal allocation of resources and is therefore expected to vary from country to country, depending on the relative importance of the seismic risk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

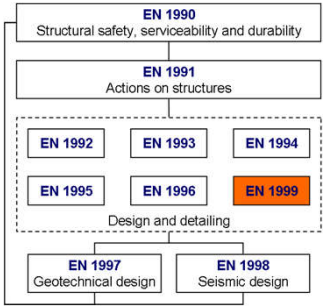
- **EN 1998 contains only those provisions that, in addition to the provisions of the other relevant EN Eurocodes, must be observed for the design of structures in seismic regions. It complements in this respect the other EN Eurocodes.**



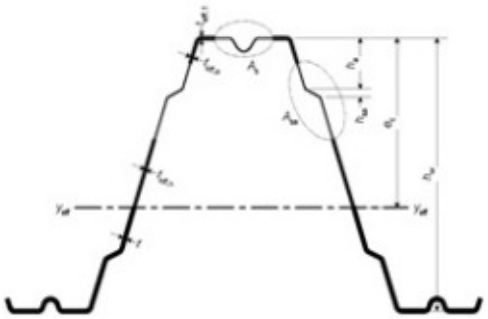
EN 1998-1:2004	Eurocode 8: Design of structures for earthquake resistance – Part 1: General rules, seismic actions and rules for buildings
EN 1998-2:2005	Eurocode 8: Design of structures for earthquake resistance – Part 2: Bridges
EN 1998-3:2005	Eurocode 8: Design of structures for earthquake resistance – 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 Directive (Council Directive 89/106/EEC) aim is to breakdown artificial barriers to trade throughout the European Union and is intended for products placed on the market
- According to the Construction Products Directive, construction products suitable for construction works need to satisfy the following six essential requirements as appropriate:
  - mechanical resistance and stability
  - safety in case of a fire
  - hygiene, health and the environment
  - safety in use
  - protection against noise
  - energy economy and heat retention

EU legislation for construction works and products

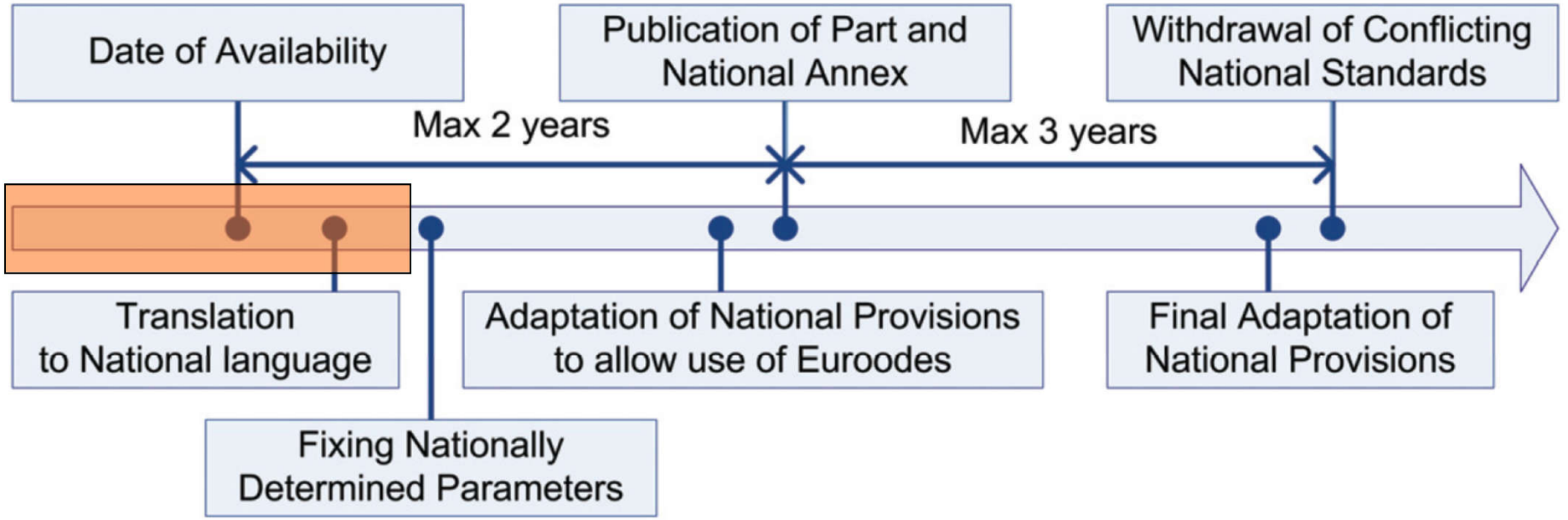
- **The Eurocodes provide common design methods, expressed in a set of European standards, which are intended to be used as reference documents for Member States to:**
  - **prove the compliance of building and civil engineering works or parts thereof with Essential Requirement n°1 Mechanical resistance and stability (including such aspects of Essential Requirement n°4 Safety in use, which relate to mechanical resistance and stability) and a part of Essential Requirement n°2 Safety in case of fire, including durability**
  - **express in technical terms , these Essential Requirements applicable to the works and parts thereof;**
  - **determine the performance of structural components and kits with regard to mechanical resistance and stability and resistance to fire, insofar as it is part of the information accompanying CE marking**

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**

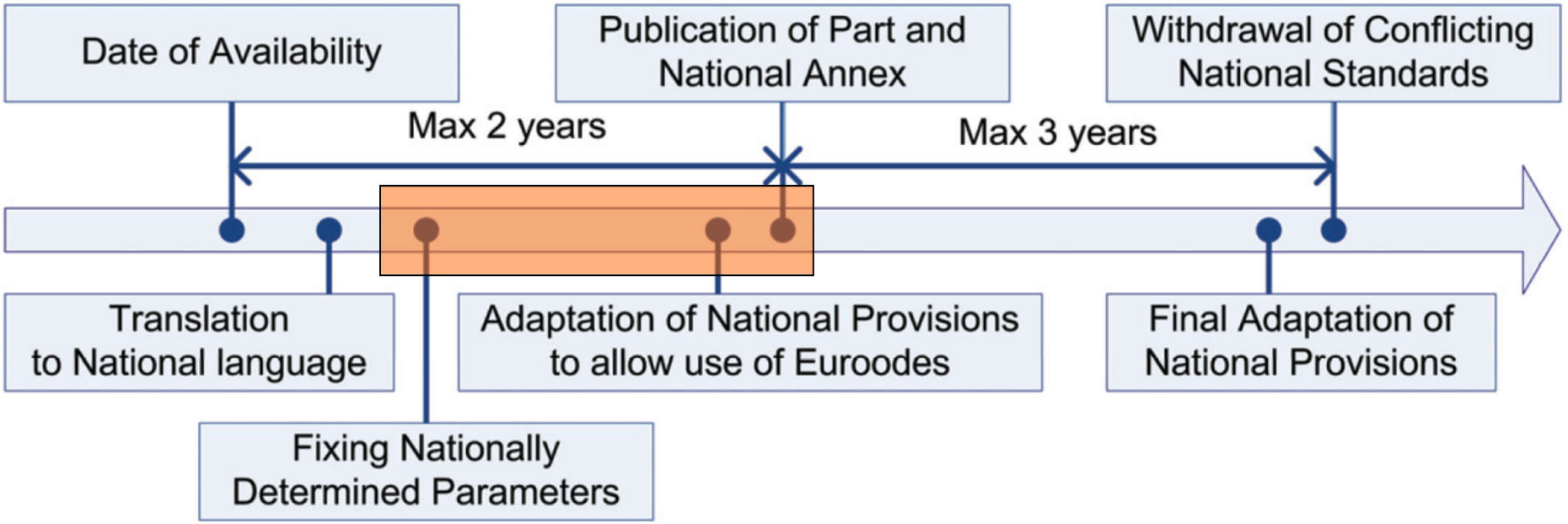
Implementation of the Eurocodes

- **The implementation of an EN Eurocode Part has three phases:**
  - **Translation period (max 1 year). The National Standards Bodies may start the translation of a Eurocode Part in authorised national languages at the latest at the Date of Availability.**



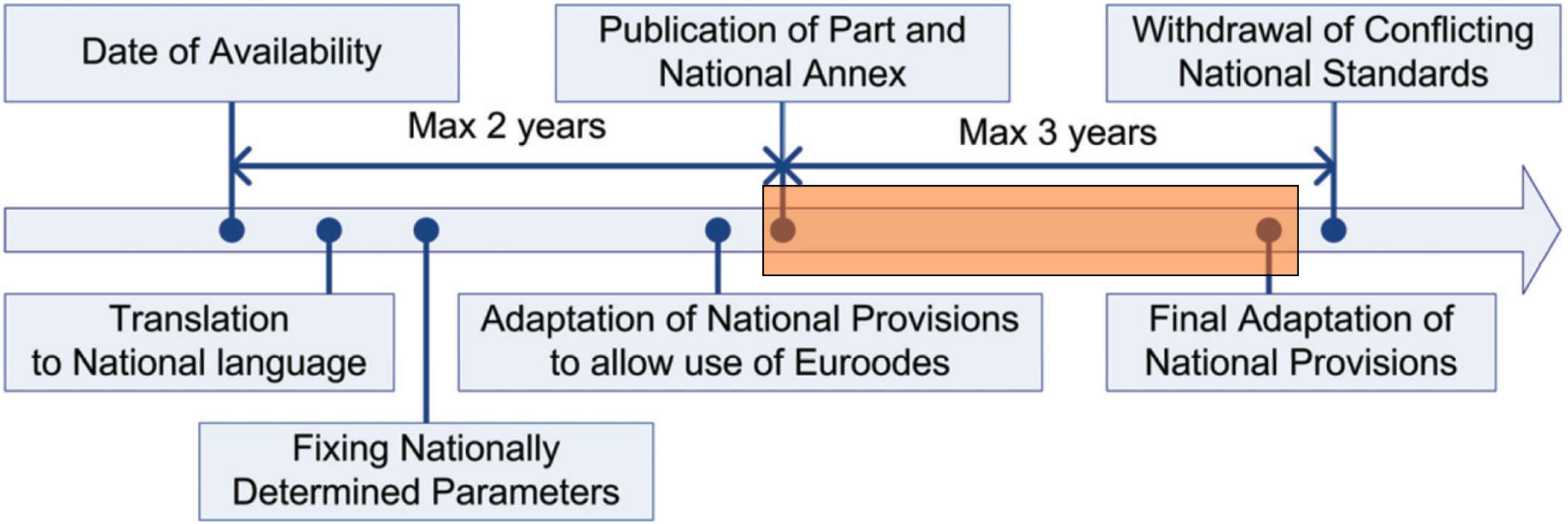
Implementation of the Eurocodes

– **National Calibration period (max 2 years). The Member States should fix the Nationally Determined Parameters. At the end of this period, the national version of the EN Eurocode Part with the National Annex will be published by the National Standards Bodies. Also, the Member States should adapt the National Provisions so that the Eurocode Part can be used on their territory.**



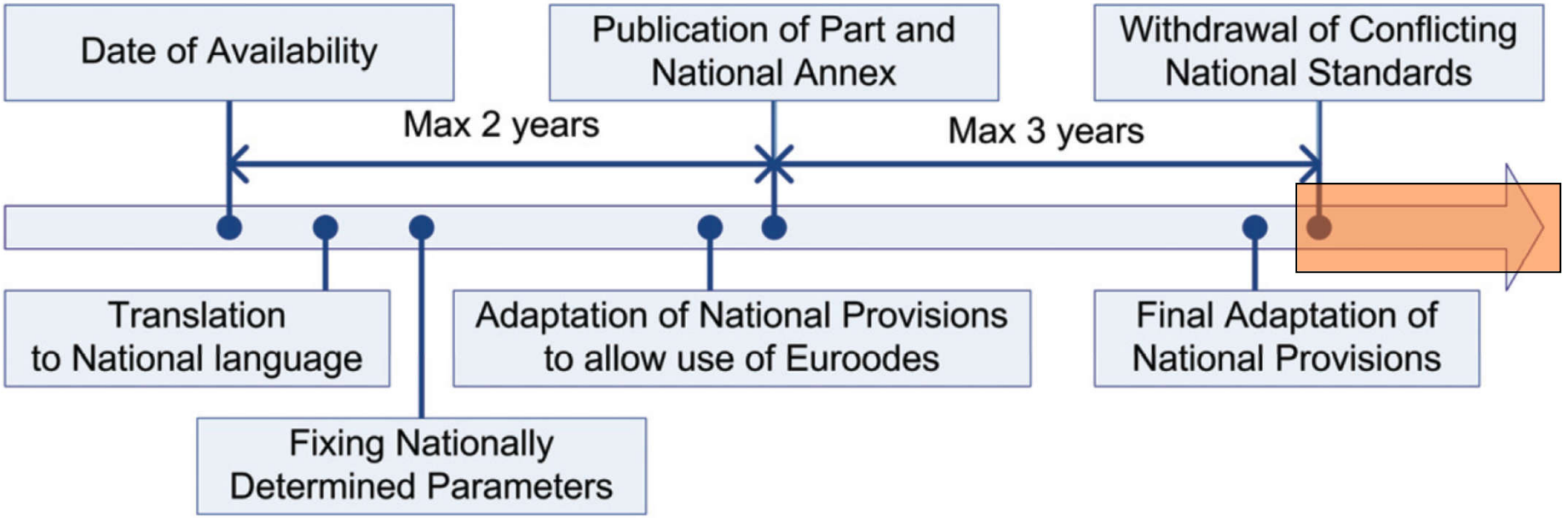
Implementation of the Eurocodes

– **Coexistence period. During the coexistence period, which starts at the end of the National Calibration period, the Eurocode Part can be used, just as the presently existing national system can also be used. The coexistence period of a Eurocode Package will last up to a maximum time of three years after the national publication of the last Part of a Package. Member States shall make sure that all the Parts of the related Package can be used without ambiguity on their territory by adapting their National Provisions as necessary.**



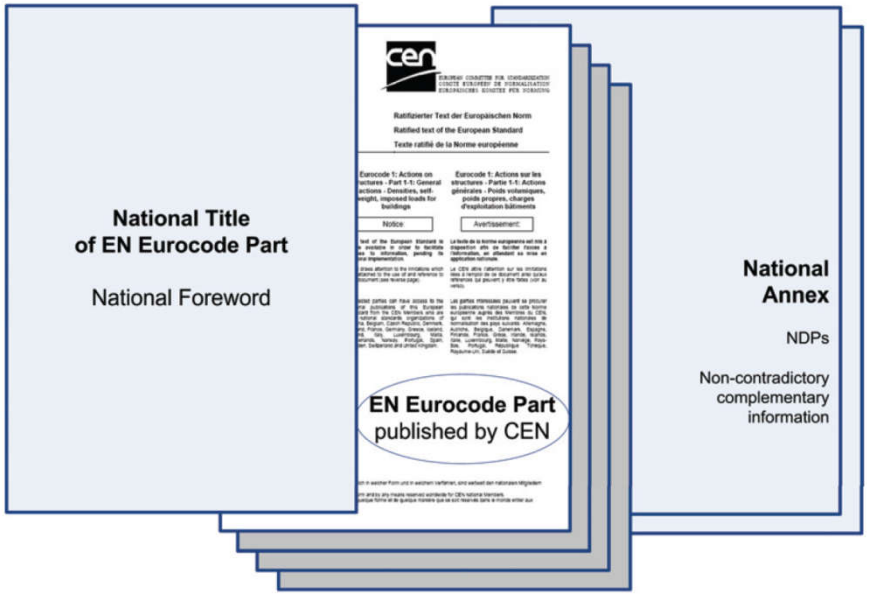
Implementation of the Eurocodes

- **All conflicting National Standards in a Package should be withdrawn a maximum of 5 years after the Date of Availability of the last available Part in the Package**
- **Following CEN rules, the Eurocodes can be used in parallel with National Standards until 2010, when all conflicting National Standards will be withdrawn**



National Standards

- The National Standard transposing the EN Eurocode Part, when published by a National Standards Body, will be composed of the EN Eurocode text preceded by the National Title page and by the National Foreword and generally followed by the National Annex
- The National Standards Bodies should normally publish the National Annex, on behalf of and with the agreement of the competent National Authorities



National Standards: National Annex

- The National Annex (NA) may contain directly, or by reference to specific provisions,
  - information on the Nationally Determined Parameters (NDPs) to be used for the design of buildings and other civil engineering works to be constructed in the country concerned.
  - It may also contain decisions on the application of informative annexes and reference to non-contradictory complementary information
- A National Annex is not necessary if a Eurocode Part contains no choice open for Nationally Determined Parameters, or if a Eurocode Part is not relevant for the Member State (e.g. EN 1998 for seismic design for some countries)

National Standards: NDPs

- Eurocodes "recognise the responsibility of regulatory authorities in each Member State and have safeguarded their right to determine values related to safety matters at national level where these continue to vary from State to State".
- National choice is provided by the Eurocodes with sets of recommended values, classes, symbols and alternative methods to be used as NDPs.
- The NDPs account for possible differences in geographical or climatic conditions, or in ways of life, as well as different levels of protection that may prevail at national, regional or local level.
- When the Eurocodes are used for the design of construction works, or parts thereof, the NDPs of the Member State on whose territory the works are located shall be applied.

Current Romanian codes

- Standards issued and maintained by ASRO - Asociaţia de Standardizare din România (Romanian Standards Association): "SR-EN“, "STAS", "SR"
- Application of standards issued by ASRO are optional (law 39/1998 and 355/2002). Application of standards can become compulsory only when stipulated by a technical regulation issued by an authority
- Authority - Ministry of Regional Development and Public Administration (Ministerul Dezvoltarii Regionale si Administratiei Publice - MDRAP)
- MDRAP issues a list of technical regulations in force, most available in "Buletinul Constructiilor" published by URBAN-INCERC (Institutul Naţional de Cercetare-Dezvoltare în Construcţii, Urbanism şi Dezvoltare Teritorială Durabilă)
- Current design codes in Romania are in continuous evolution, as new European standards are implemented

Some of the current Romanian codes

- **CR 0-2012: “Cod de proiectare. Bazele proiectării construcţiilor”**
- **CR 1-1-3/2012: ”Cod de proiectare. Evaluarea acţiunii zăpezii asupra construcţiilor”**
- **CR 1-1-4/2012: “Cod de proiectare. Evaluarea acţiunii vântului asupra construcţiilor”**
- **P 100-1/2013: “Cod de proiectare seismică – Partea I – Prevederi de proiectare pentru clădiri”**