

EU-Russia Regulatory Dialogue: Construction Sector Subgroup

Seminar 'Bridge Design with Eurocodes'

JRC-Ispra, 1-2 October 2012

Organized and supported by

European Commission

DG Joint Research Centre
DG Enterprise and Industry

Russian Federation

Federal Highway Agency, Ministry of Transport

European Committee for Standardization

TC250 Structural Eurocodes

General Introduction to the Eurocode Bridge Parts

Professor Steve Denton

Engineering Director, Parsons Brinckerhoff
Visiting Professor, University of Bath

Agenda

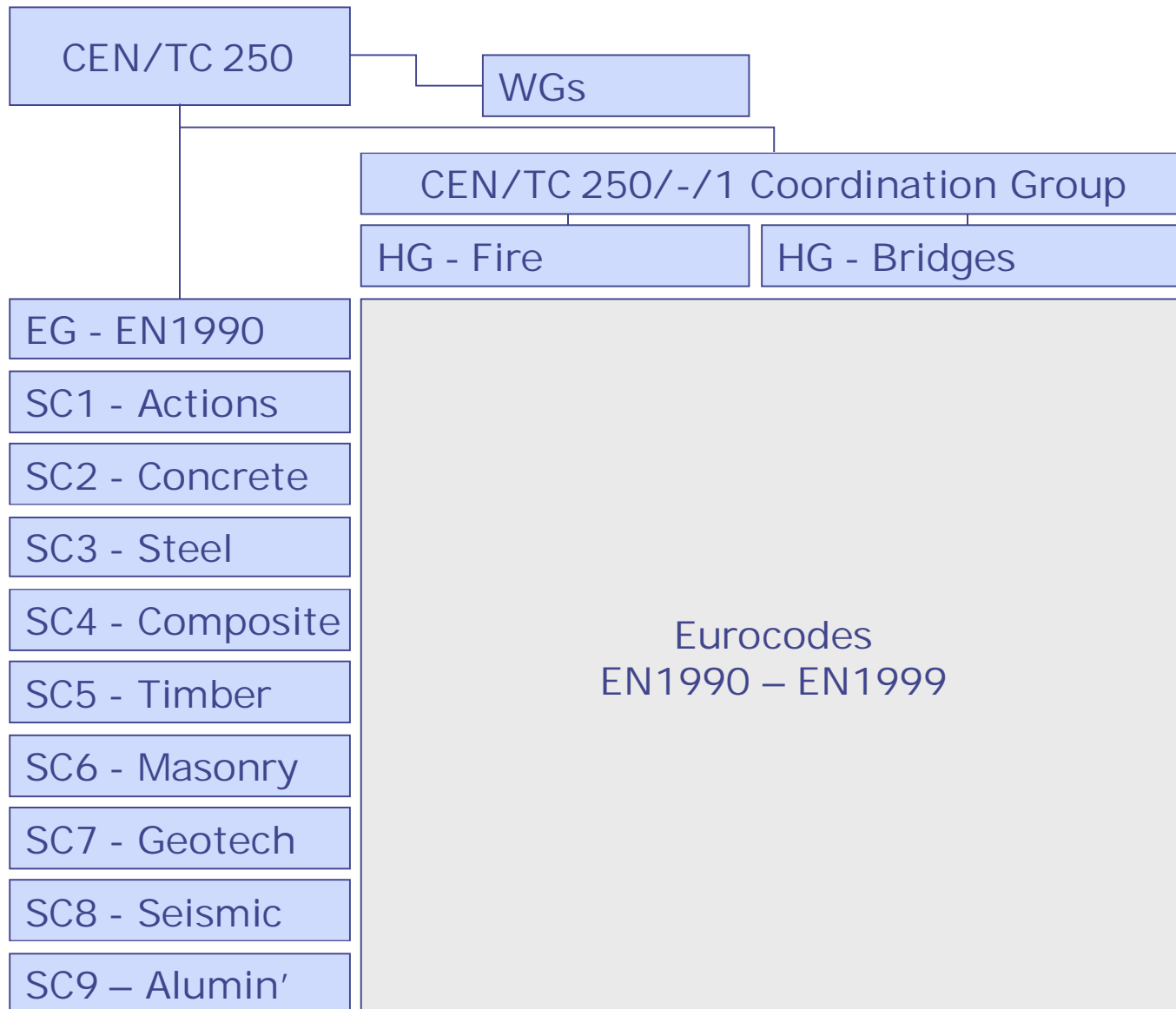
- Introduction
- Background to the Eurocode Structure
- Overview of the Eurocodes for Bridges
- Experience in design projects
- Conclusions

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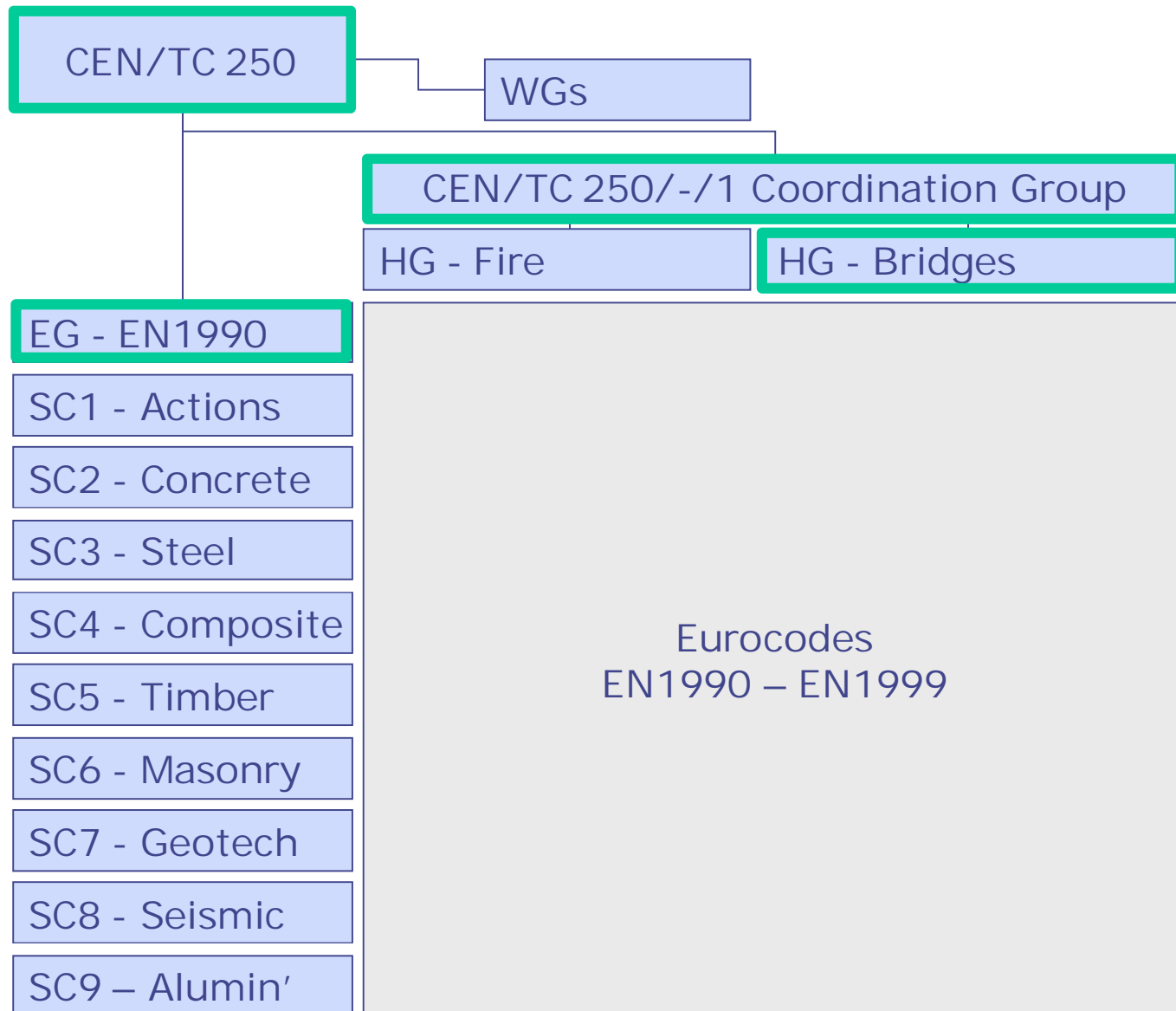
- Engineering Director, Parsons Brinckerhoff
- Visiting Professor, University of Bath
- Eurocodes experience includes:
 - Member of key National and International Standards Committees
 - Advisor to UK Highway and Rail authorities
 - Implementation strategy and technical advice
 - Development of Standards, National Annexes, Implementation guides
 - Over 70 three-day courses given in UK to clients and designers
 - Pioneering design projects
 - Conferences



TC 250 Committee Structure



TC 250 Committee Structure



Presentation objectives

- Introduce the structure of the Eurocodes for bridges
- Explain aspects of the background to their development
... and how this has influenced their structure and style
- Outline some UK implementation experience

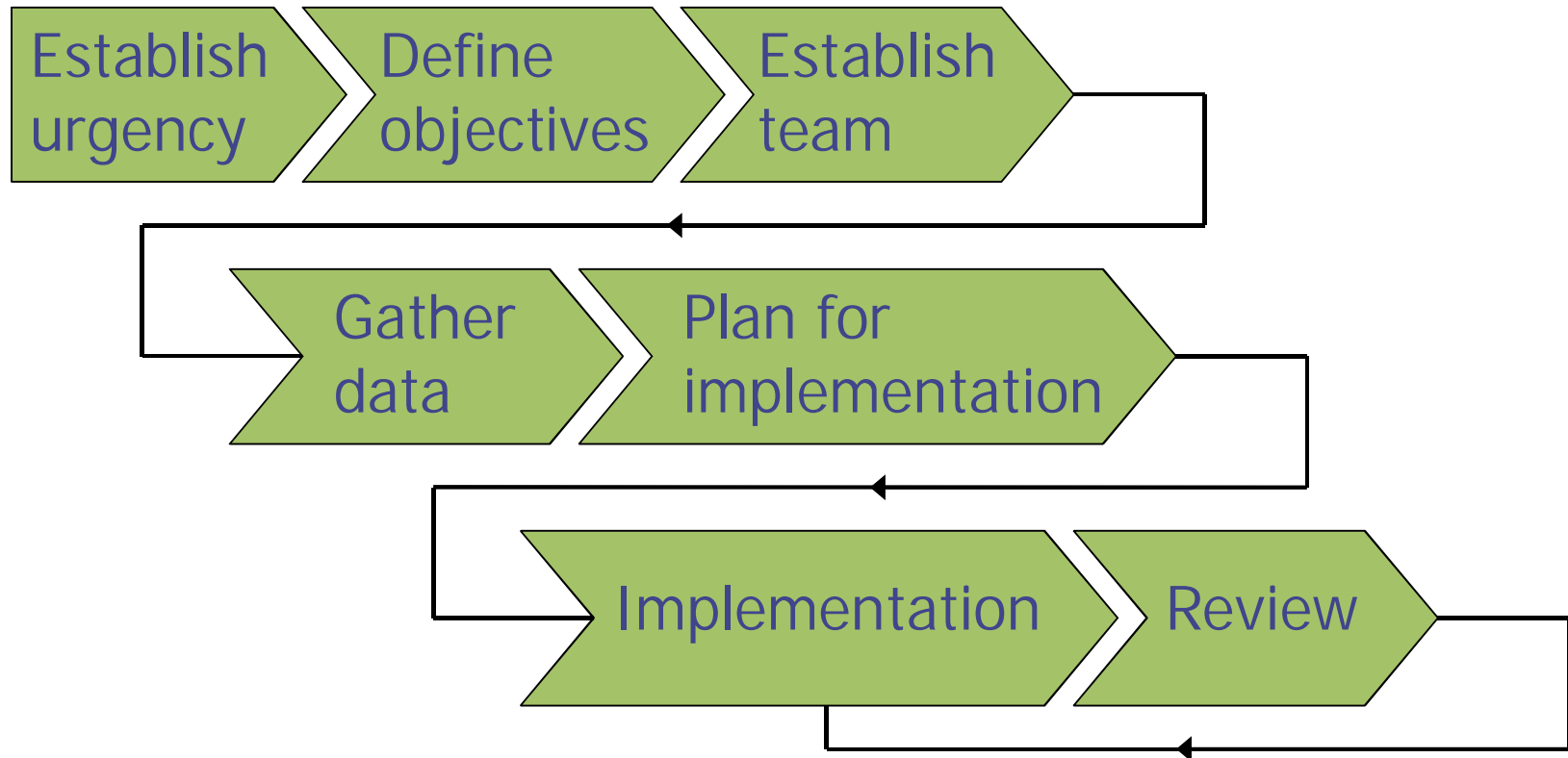
Implementation Strategy



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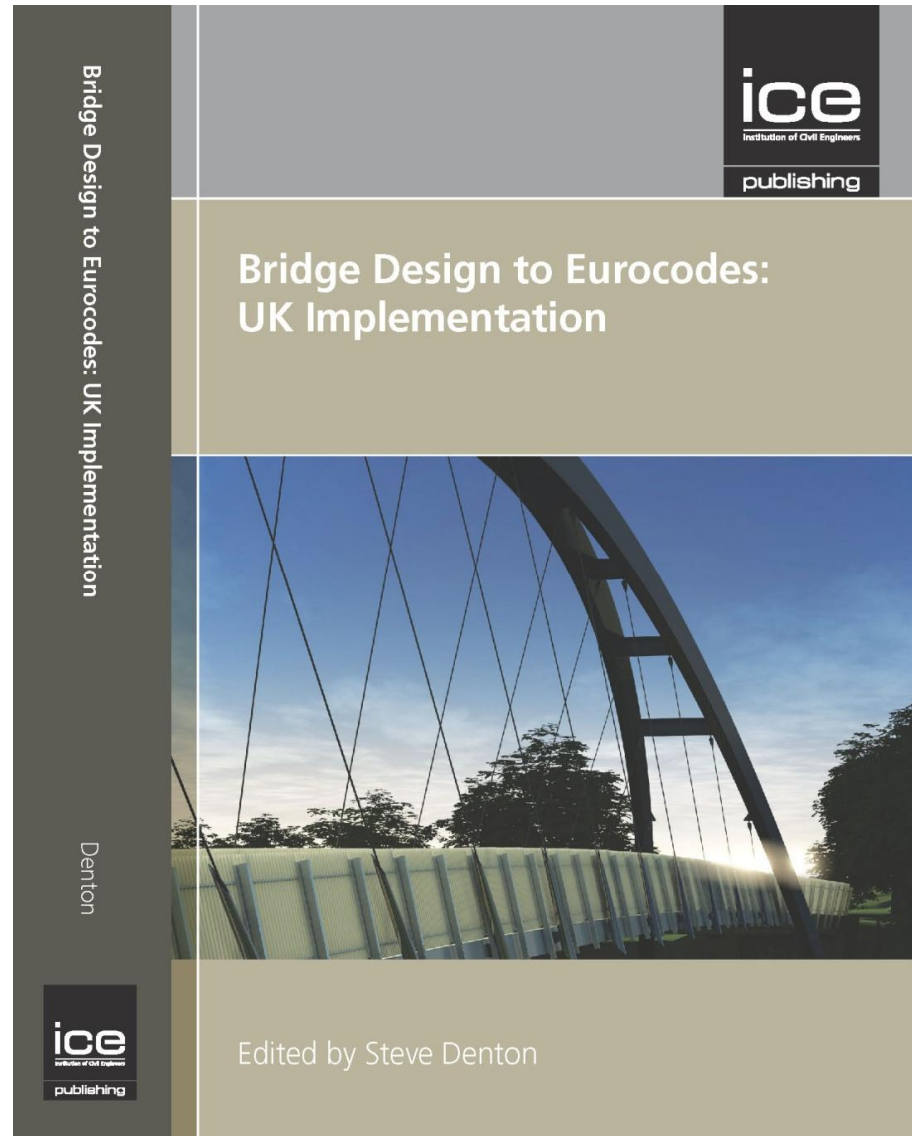
Implementation experience



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Design examples – JRC sponsored Vienna workshop



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JRC Scientific and Technical Reports



Bridge Design to Eurocodes Worked examples

Worked examples presented at the Workshop "Bridge Design to Eurocodes", Vienna, 4-6 October 2010

Support to the implementation, harmonization and further development of the Eurocodes

Y. Bouassida, E. Bouchon, P. Crespo, P. Croce, L. Davaine, S. Denton, M. Feldmann, R. Frank,
G. Hanswille, W. Hensen, B. Kollas, N. Malakatas, G. Mancini, M. Ortega, J. Raout, G. Sedlacek, G. Tsionis



Editors
A. Athanopoulou, M. Poljansek, A. Pinto
G. Tsionis, S. Denton

EUR 25193 EN - 2012

Eurocodes (EN1990 – EN1999)

Eurocodes (EN1990 – EN1999)

European standards for construction

**Eurocodes
(EN1990 – EN1999)**

**European
Execution
Standards**

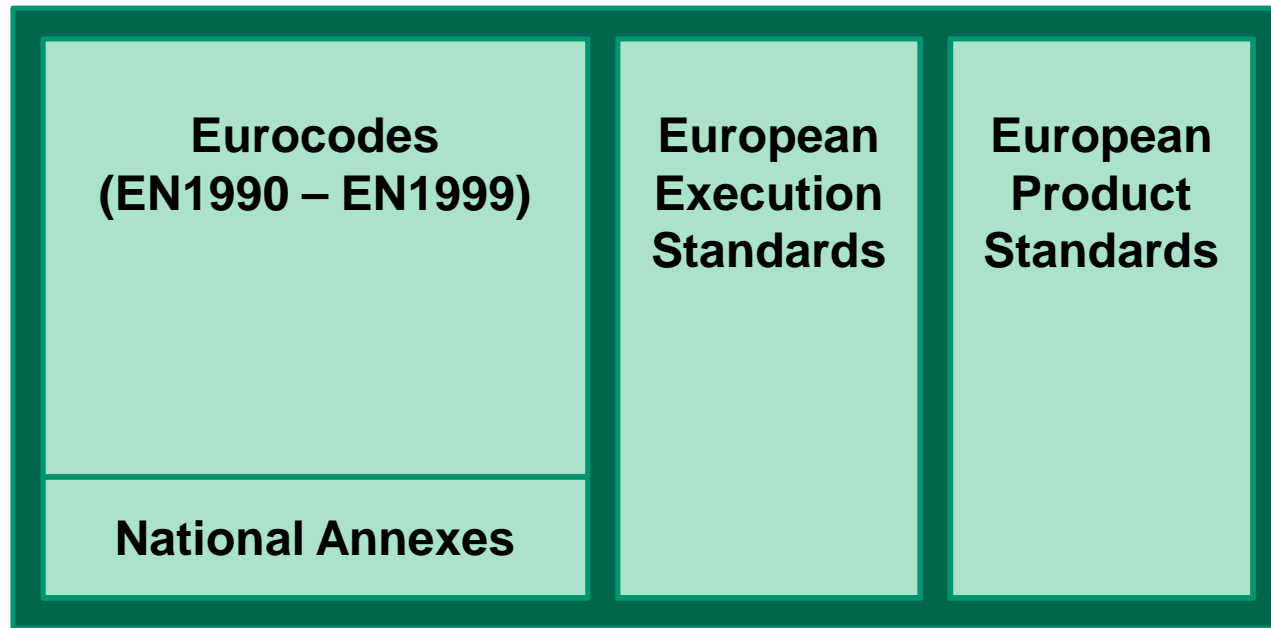
European standards for construction

**Eurocodes
(EN1990 – EN1999)**

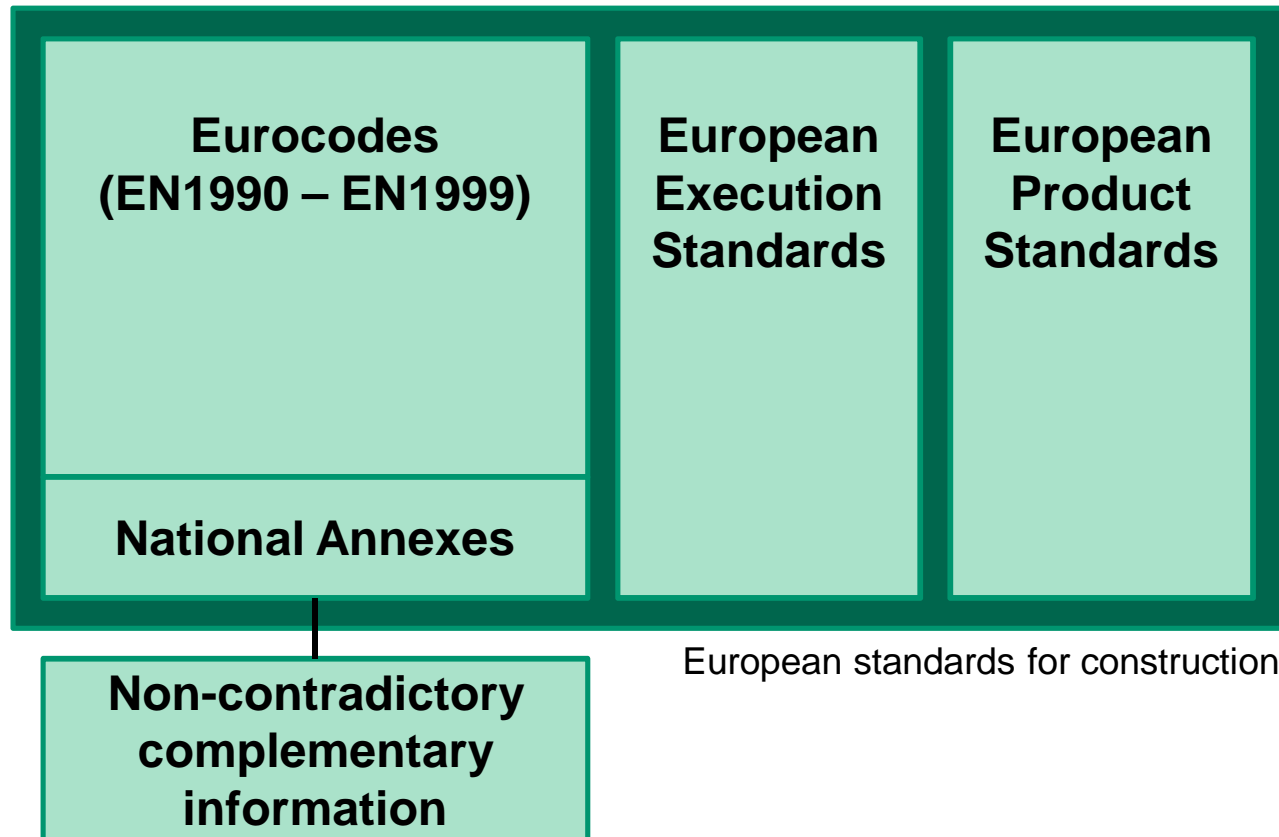
**European
Execution
Standards**

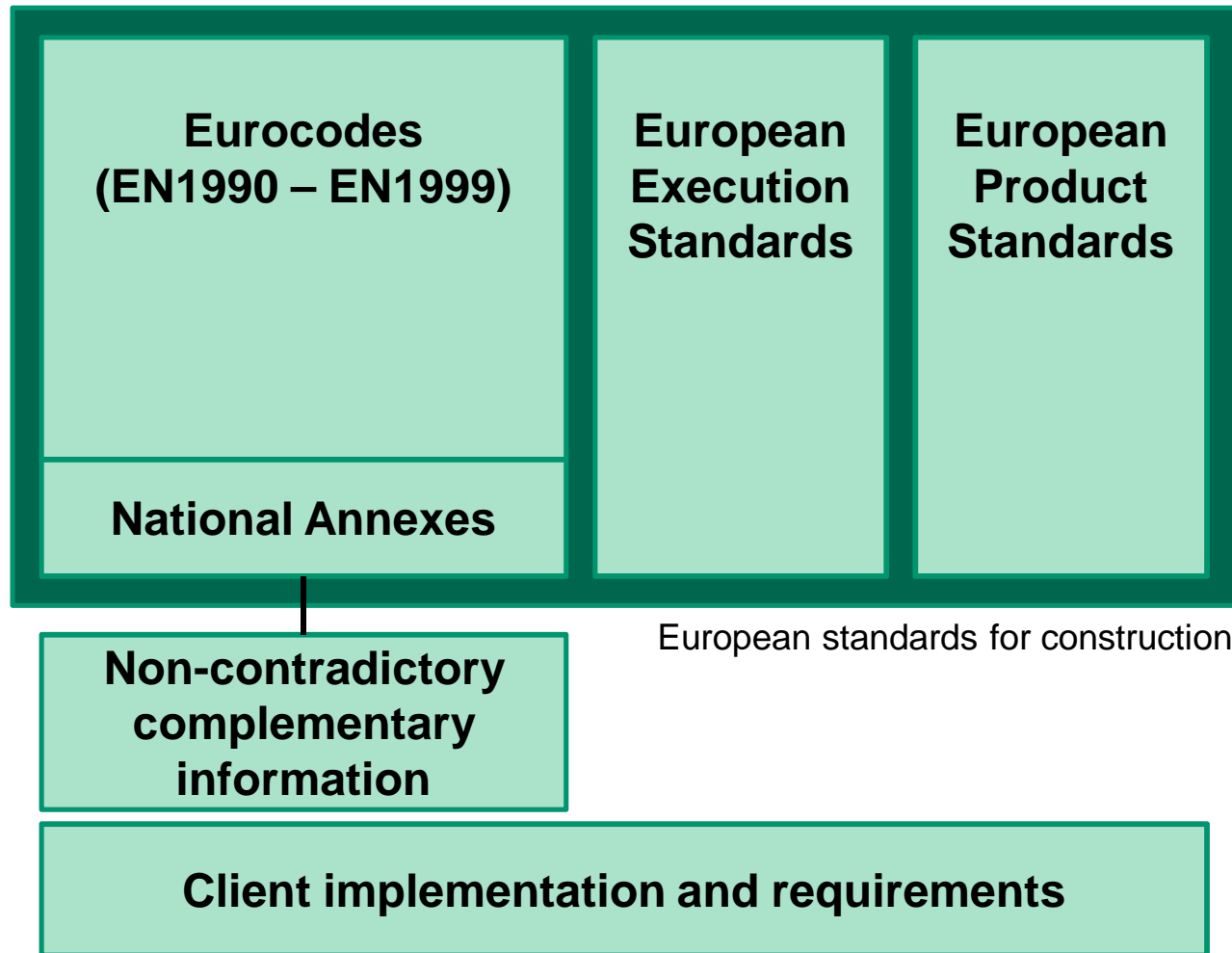
**European
Product
Standards**

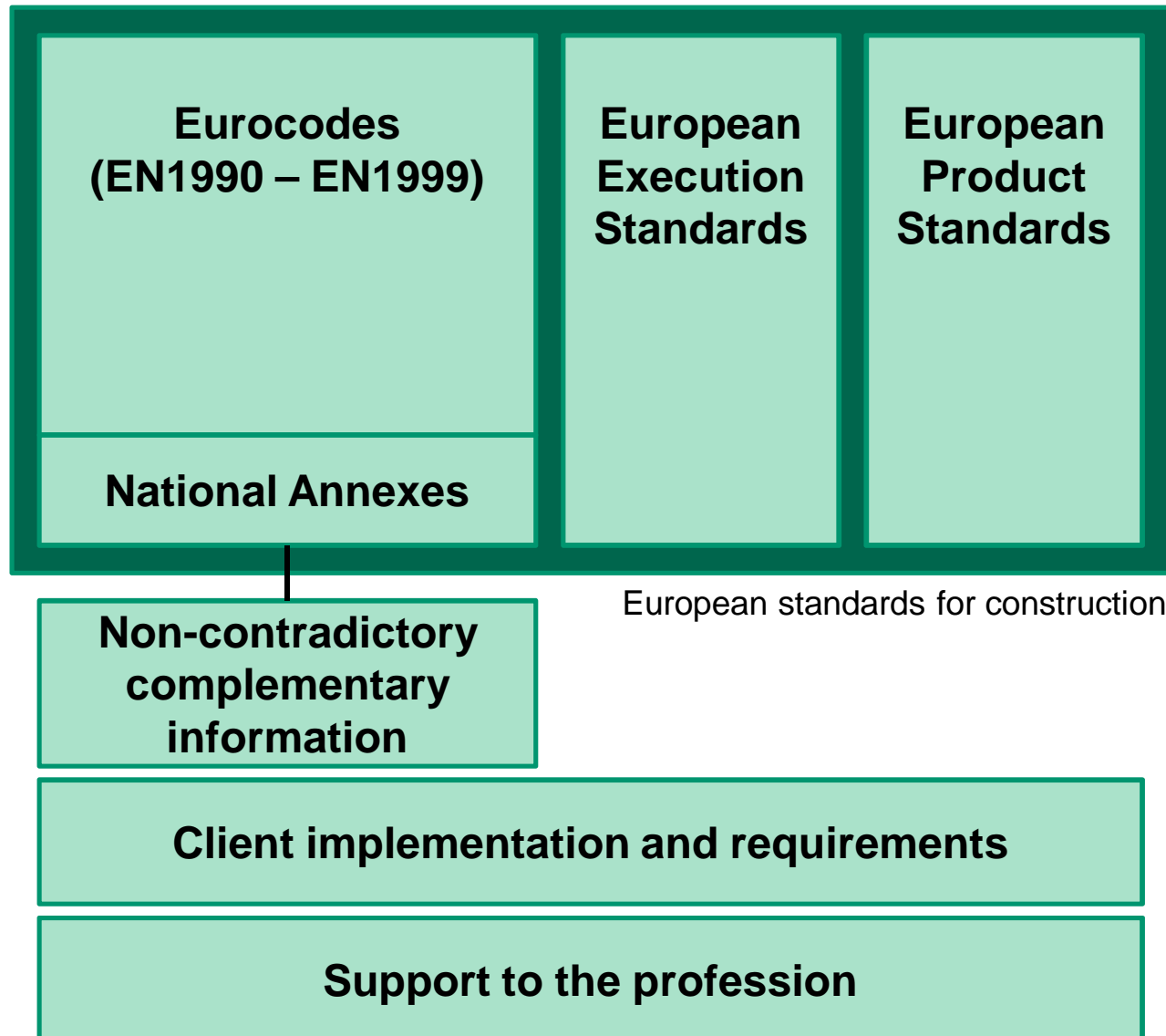
European standards for construction

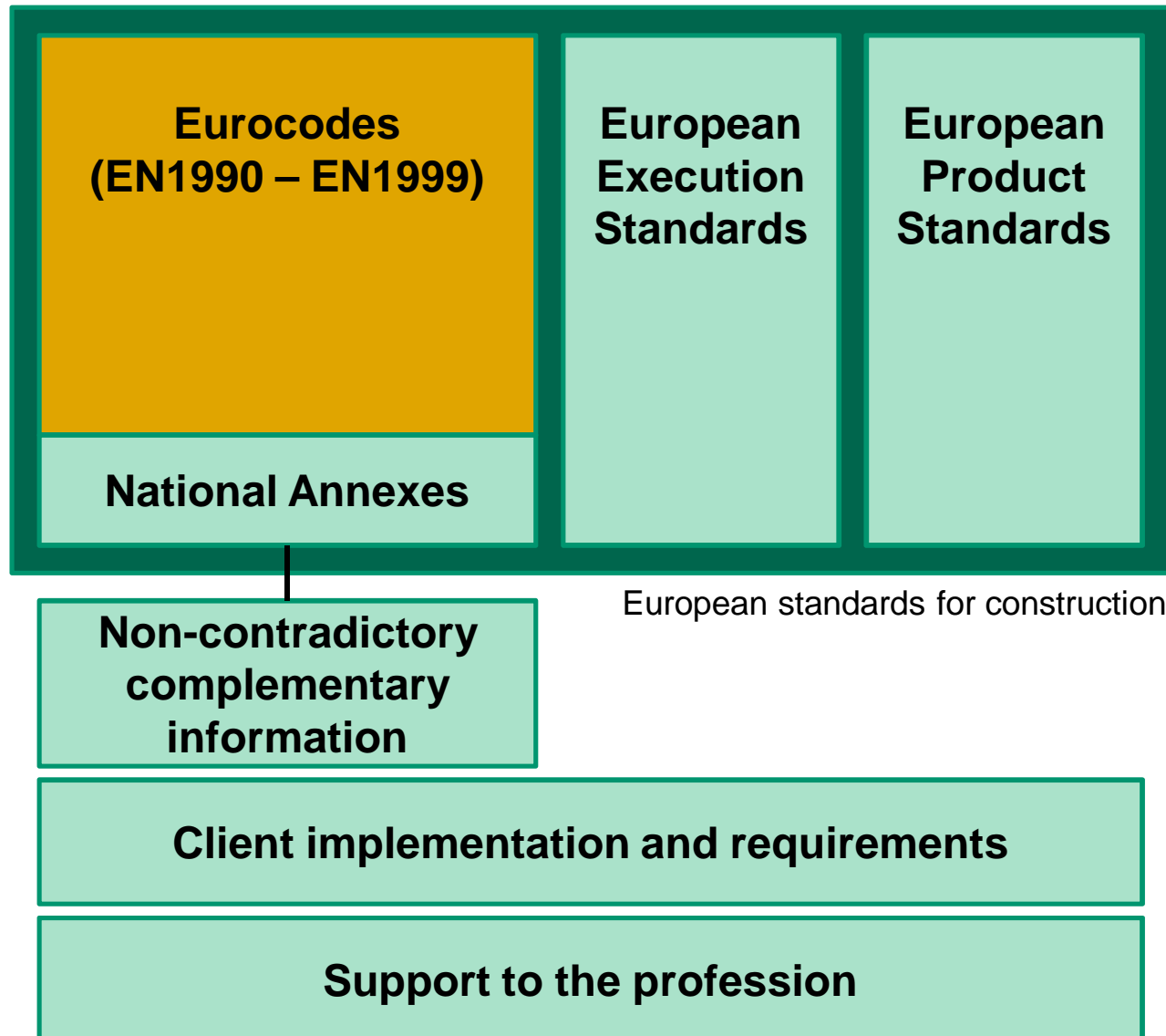


European standards for construction



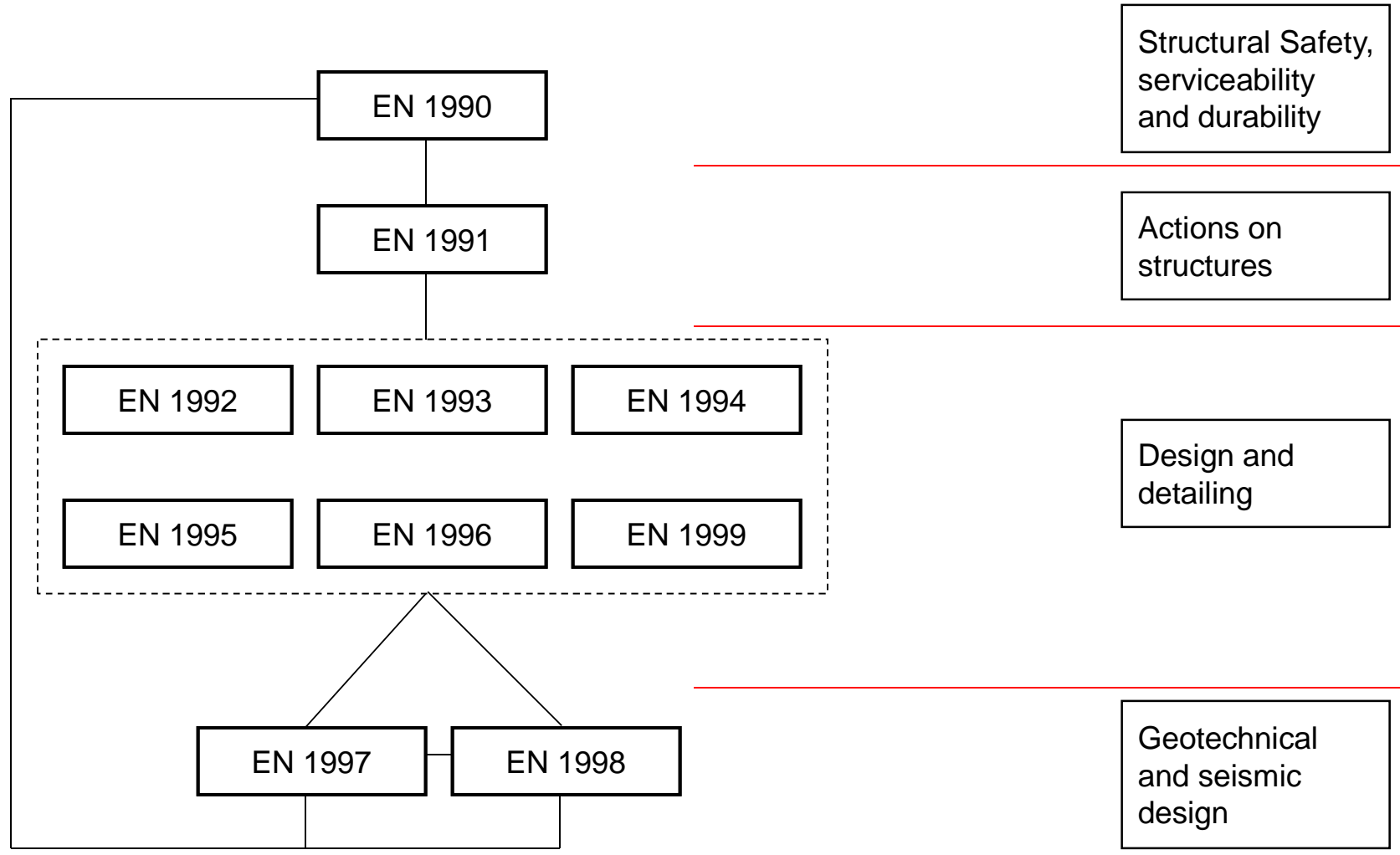




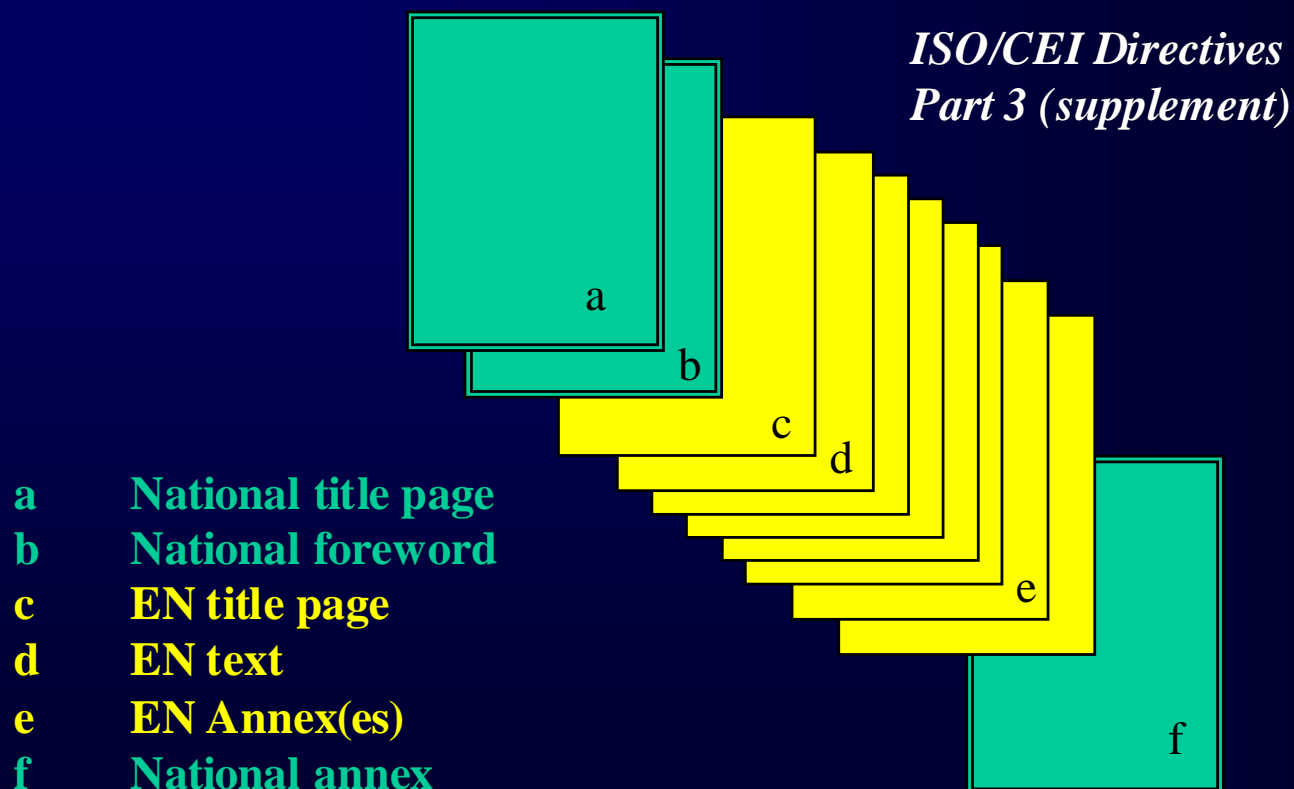


- Introduction
- Background to the Eurocode Structure
- Overview of the Eurocodes for Bridges
- Experience in design projects
- Conclusions

10 Standards with 58 Parts



Elements of the national publication of a European Standard



- Approximately 26 Eurocode Parts have content relevant to bridge design

Reference	Name
Eurocode Basis of structural design	
EN 1990	Basis of Structural Design
EN 1990/A1	Annex A2 : Application for Bridges
Eurocode 1 Actions on structures	
EN 1991-1-1	General actions. Densities, self-weight, imposed loads for buildings
EN 1991-1-3	General actions. Snow loads
EN 1991-1-4	General actions. Wind actions
EN 1991-1-5	General actions. Thermal actions
EN 1991-1-6	General actions. Actions during execution
EN 1991-1-7	General actions. Accidental actions
EN 1991-2	Traffic loads on bridges

Eurocodes for bridge design

Reference	Name
Eurocode 2 Design of concrete structures	
EN 1992-1-1	General requirements
EN 1992-2	Concrete bridges - Design and detailing rules
Eurocode 3 Design of steel structures	
EN 1993-1-1	General requirements
EN 1993-1-5	Plated structural elements
EN 1993-1-7	General - Strength of planar plated structures loaded transversely
EN 1993-1-8	Design of joints
EN 1993-1-9	Fatigue strength
EN 1993-1-10	Material toughness and through thickness props
EN 1993-1-11	Design of structures with prefabricated tension components
EN 1993-1-12	General - Strength of planar plated structures loaded transversely
EN 1993-2	Steel bridges
EN 1993-5	Piling

Eurocodes for bridge design

Reference	Name
Eurocode 4 Design of composite steel and concrete structures	
EN 1994-2	General rules and rules for bridges
Eurocode 5 Design of timber structures	
EN 1995-1-1	Common rules and rules for buildings
EN 1995-2	Bridges
Eurocode 7 Geotechnical Design	
EN 1997-1	General Rules
Eurocode 8 Design of structures for earthquake resistance	
EN 1998-1	General rules, seismic actions and rules for buildings
EN 1998-2	Bridges

- Eurocodes have been in development since mid 1970s
- Suite of 'pre-standards' (BS ENV) introduced in 1990s
- Pre-standards replaced by 'Euro-Norm' standards (BS EN)
- Conflicting Standards withdrawn in most CEN member countries in March 2010

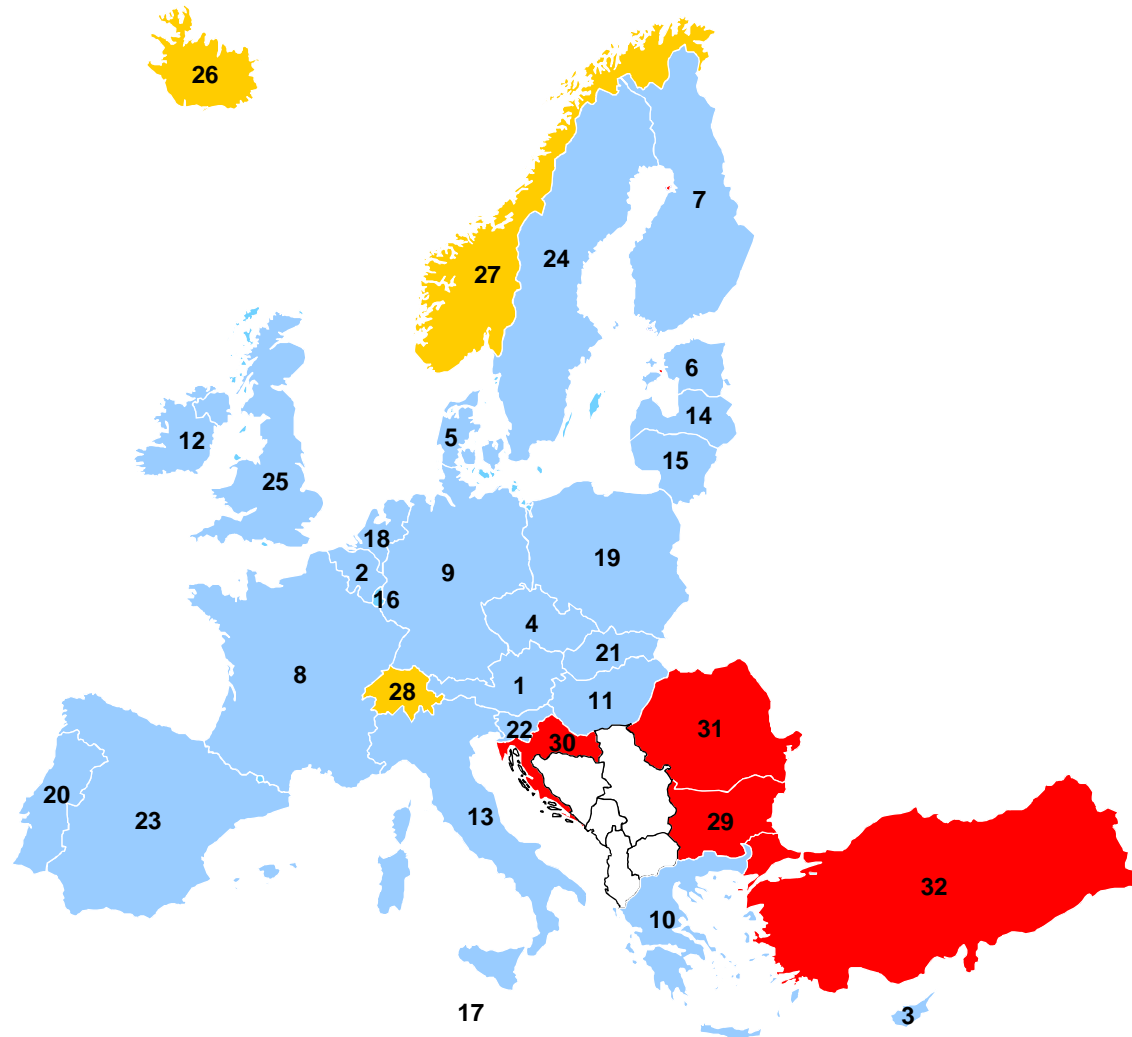
Background



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Commission

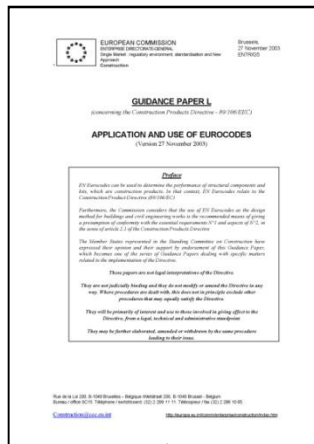
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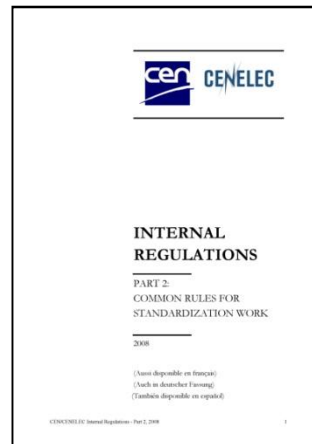


Guidelines and regulations

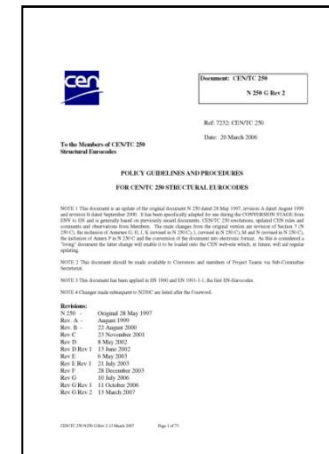
European commission



CEN



CEN / TC 250



Eurocodes

All Eurocode Parts required a positive vote from CEN membership



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Commission

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- The need for positive vote from members has impacted:
 - Style of Standards
 - National determined parameters
 - Flexibility and choice
 - Emphasis on principles

All Eurocode Parts required a positive vote from CEN membership



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Commission

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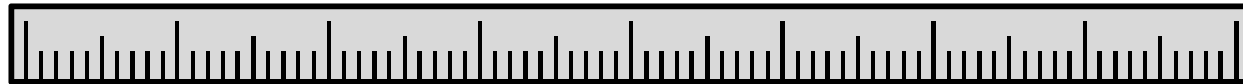
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- The need for positive vote from members has impacted:
 - Style of Standards
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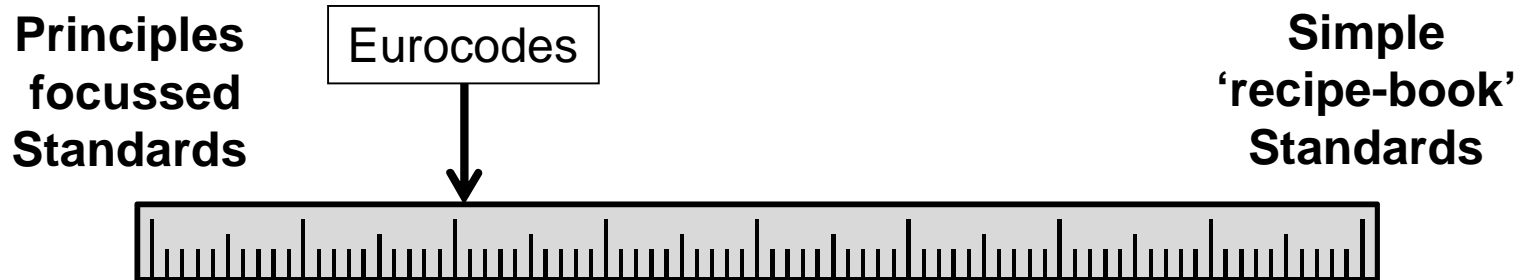
All Eurocode Parts required a positive vote from CEN members

**Principles
focussed
Standards**

**Simple
'recipe-book'
Standards**



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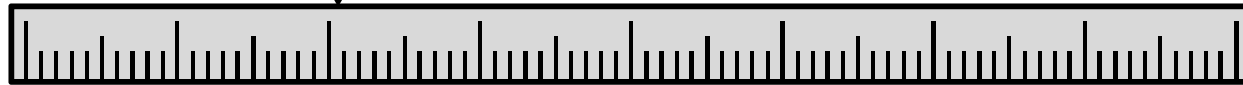


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**Principles
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Eurocodes

**Simple
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**First
use**

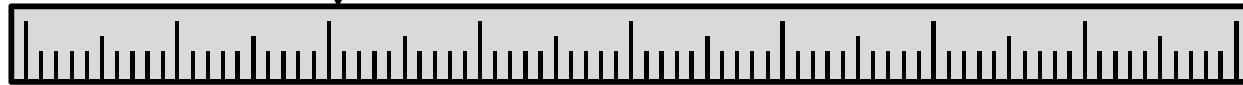
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**Principles
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Standards**

Eurocodes



**Simple
'recipe-book'
Standards**



**First
use**

Complicated,
cumbersome?

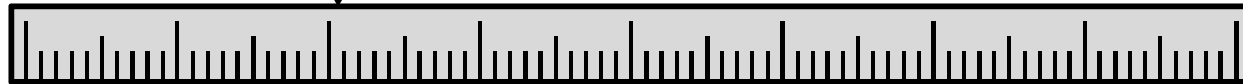
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**Principles
focussed
Standards**

Eurocodes



**Simple
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Standards**

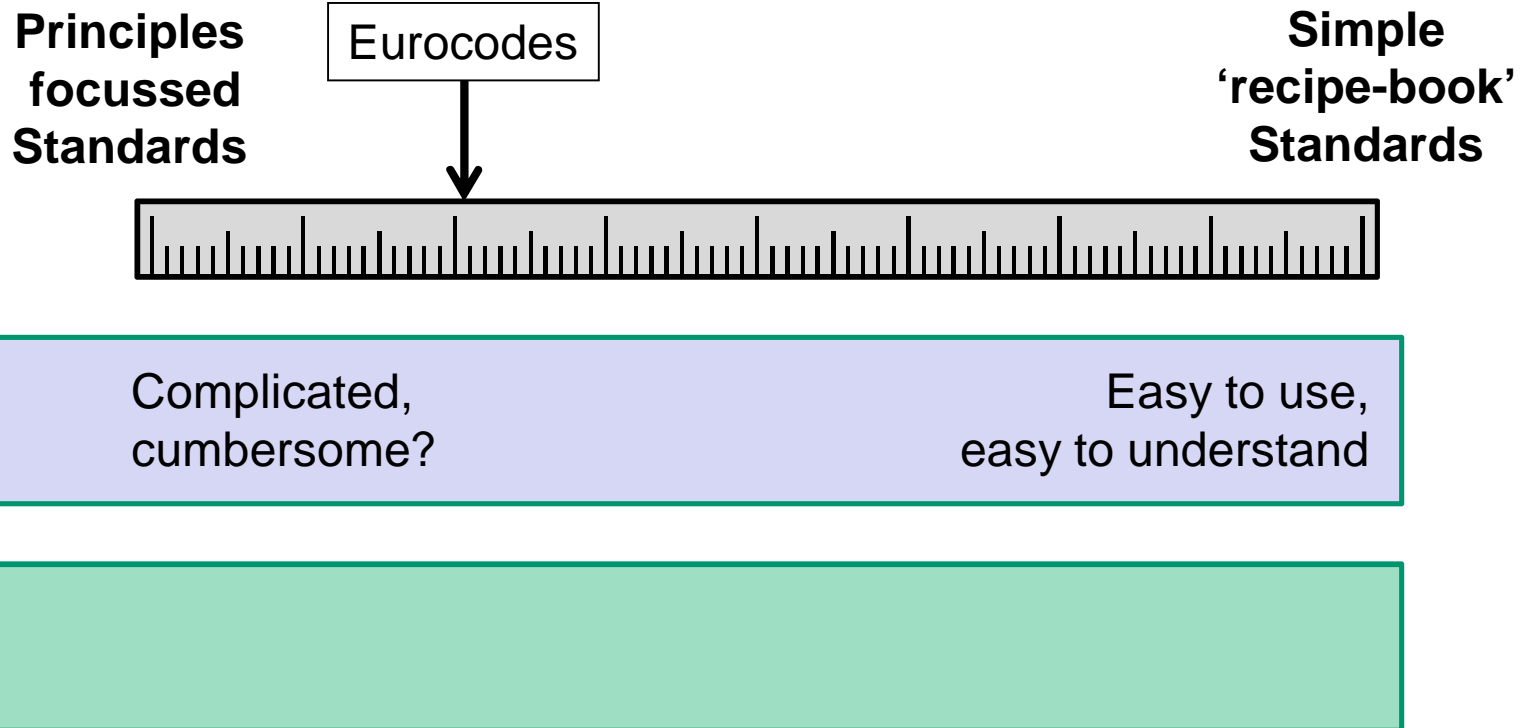


**First
use**

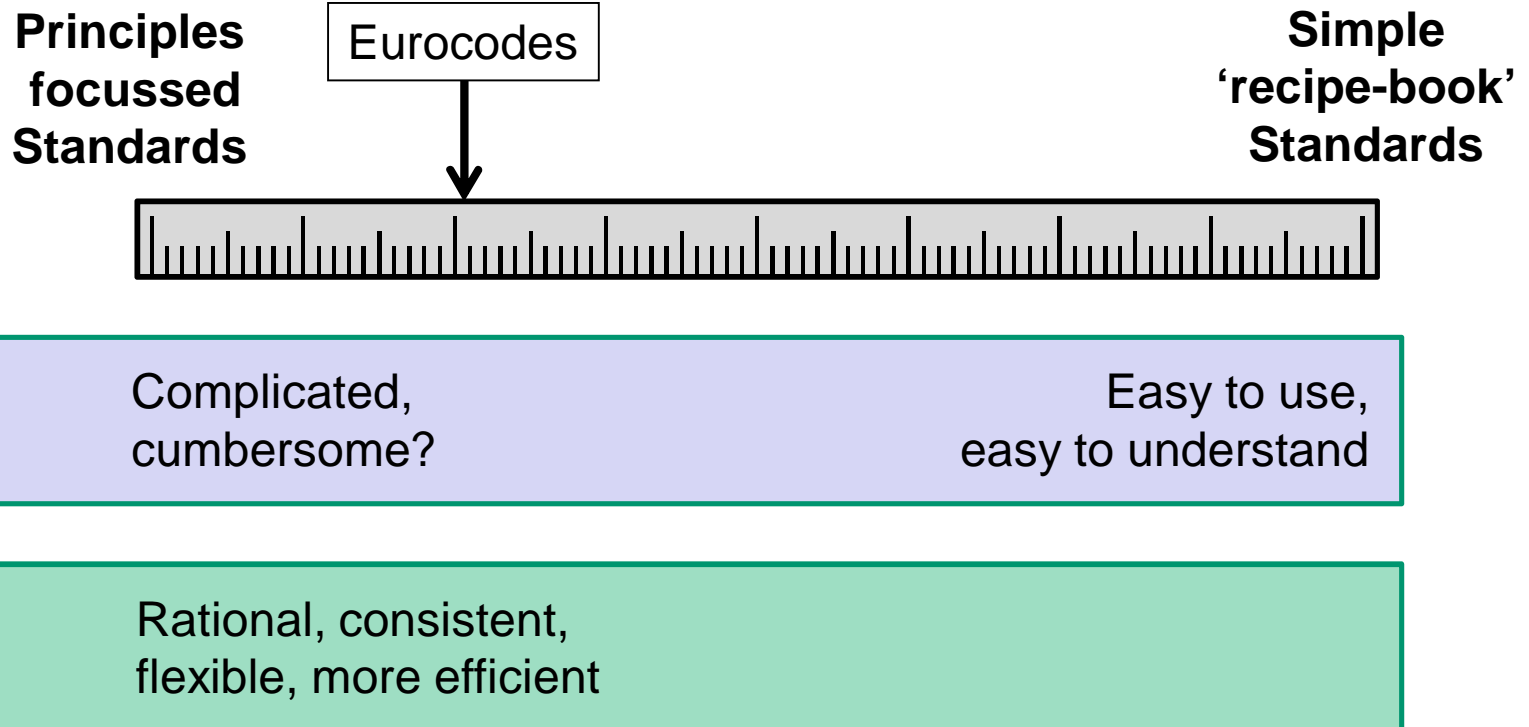
Complicated,
cumbersome?

Easy to use,
easy to understand

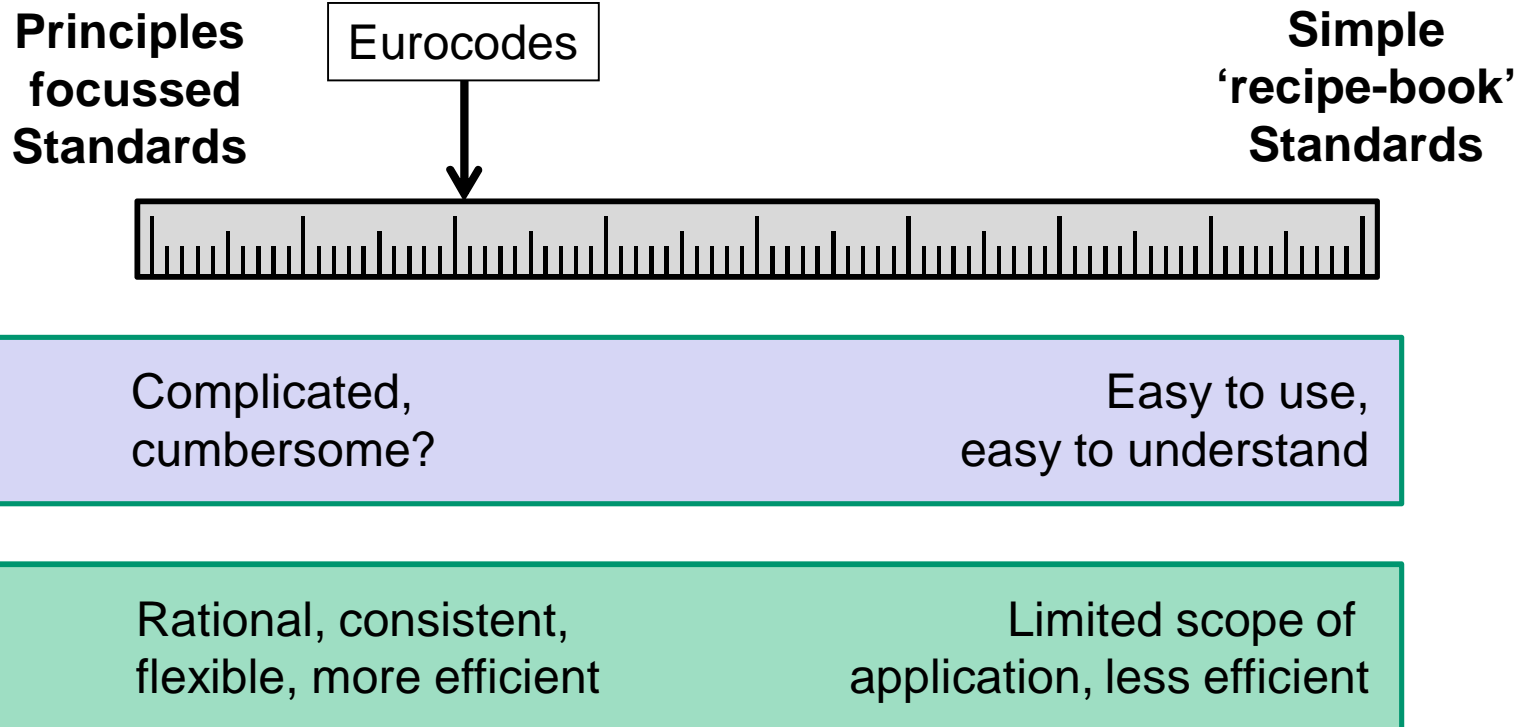
All Eurocode Parts required a positive vote from CEN members



All Eurocode Parts required a positive vote from CEN members



All Eurocode Parts required a positive vote from CEN members



Eurocodes use consistent structure



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	EN 1992-1-1 & EN 1992-2 Concrete bridges	EN 1993-1-1 & EN 1993-2 Steel bridges	EN 1994-2 Composite bridges
Section 1	General	General	General
Section 2	Basis of design	Basis of design	Basis of design
Section 3	Materials	Materials	Materials
Section 4	Durability and cover to reinforcement	Durability	Durability
Section 5	Structural analysis	Structural analysis	Structural analysis
Section 6	Ultimate limit states	Ultimate limit states	Ultimate limit states
Section 7	Serviceability limit states	Serviceability limit states	Serviceability limit states
Section 8	Detailing of reinforcement and prestressing tendons	Fasteners, welds, connections and joints	Precast concrete slabs in composite bridges
Section 9	Detailing of members	Fatigue assessment	Composite plates in bridges
Section 10	Additional rules for precast concrete	Design assisted by testing (EN 1993-2 only)	
Section 11	Lightweight concrete		
Section 12	Plain and lightly reinforced concrete		
Section 13	Design for the execution stages (EN 1992-2 only)		



Core sections



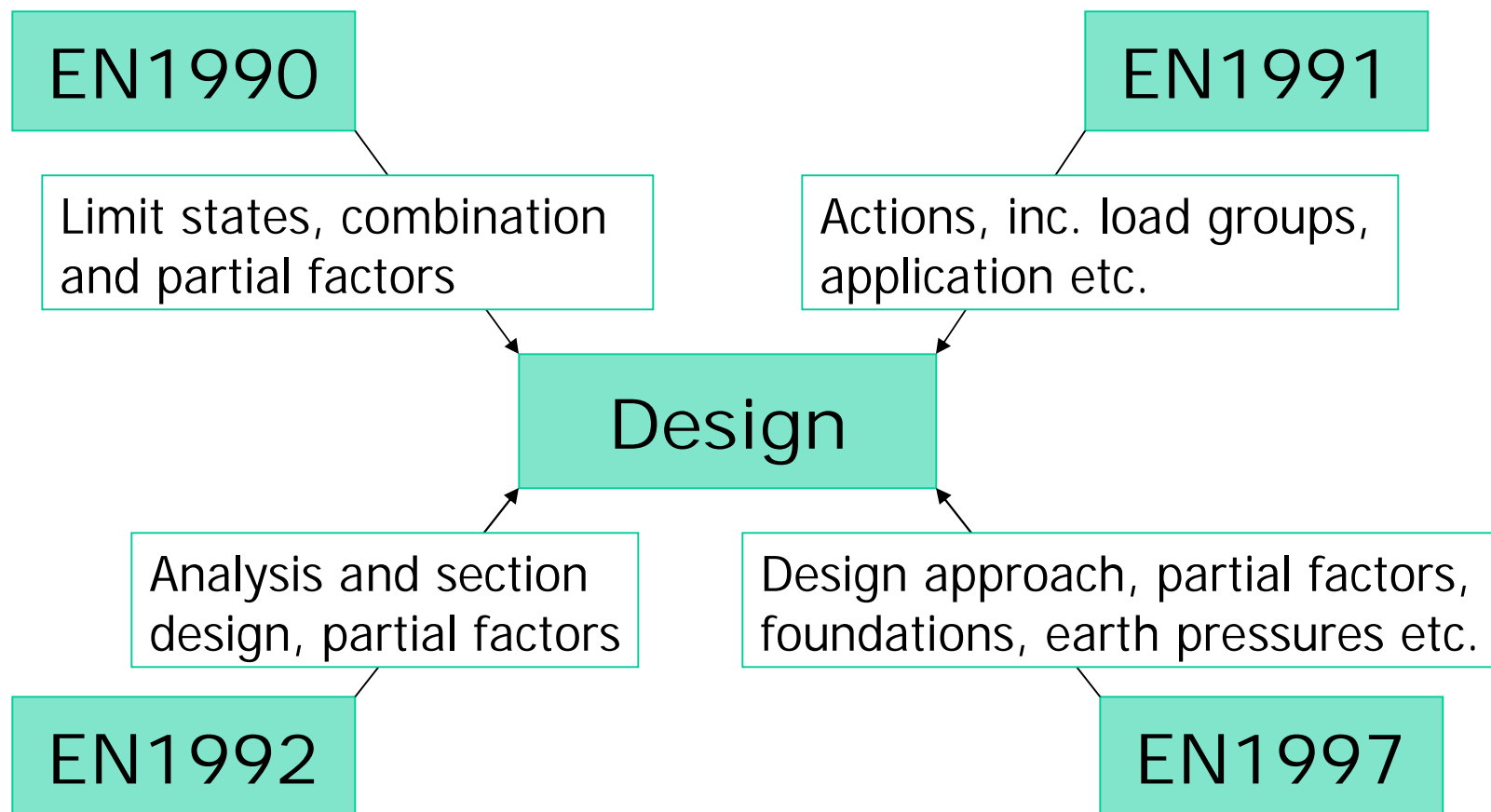
Material-specific sections

- Introduction
- Background to the Eurocode Structure
- Overview of the Eurocodes for Bridges
- Experience in design projects
- Conclusions

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 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 for earthquake resistance
EN 1999	Eurocode 9: Design of aluminium structures

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 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 for earthquake resistance
EN 1999	Eurocode 9: Design of aluminium structures

Eurocodes required to design Concrete bridge



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 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 for earthquake resistance
EN 1999	Eurocode 9: Design of aluminium structures

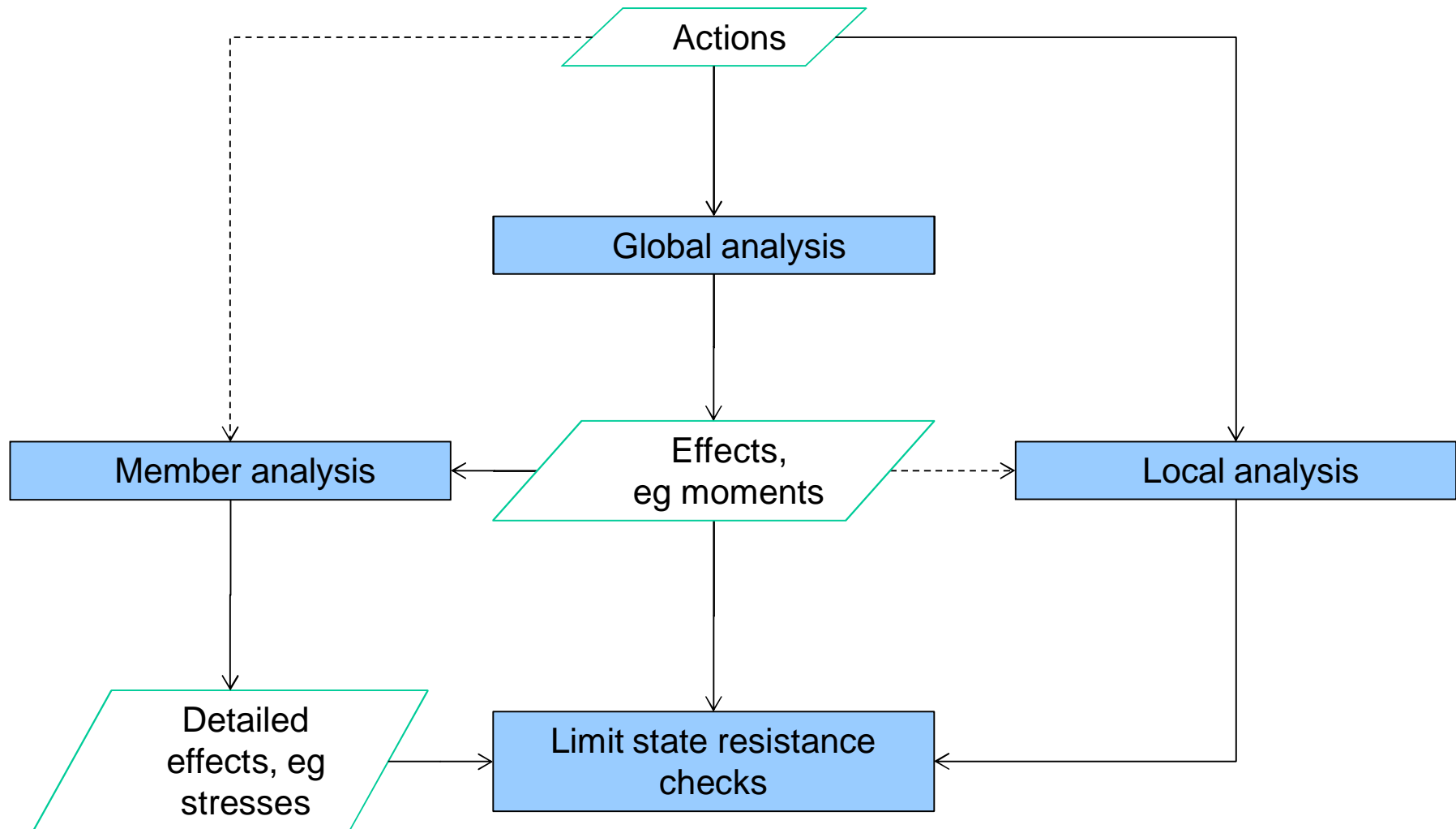
- 1 General
- 2 Requirements
- 3 Principles of Limit State Design
- 4 Basic Variables
- 5 Structural Analysis and Design Assisted by Testing
- 6 Verifications by the Partial Factor Method

Annexes



Annex A1	Application for Buildings
Annex A2	Application for Bridges
Annex B	Management of Structural Reliability for Construction Works
Annex C	Basis for Partial Factor Design and Reliability Analysis
Annex D	Design Assisted by Testing

Analysis of bridges



Key Eurocode requirements

Models / idealisations used for analysis

Should be based on established engineering theory and practice, & if necessary, verified experimentally

Should be appropriate to the problem / limit state / stage of construction being considered

Should reflect behaviour with appropriate accuracy

Should be consistent with design assumptions

EN1990	Concrete EN1992	Steel EN1993	Composite EN1994
✓ 5.1.1 (3)			
✓ 5.1.1 (2)	✓ 5.1.1 (4),(5)	✓ 5.1.1 (1)	
✓ 5.1.1 (2)	✓ 5.1.1 (4)-(7)	✓ 5.1.1 (2)	✓ 5.1.1 (1)
		✓ 5.1.1 (3)	✓ 5.1.1 (1)

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 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 for earthquake resistance
EN 1999	Eurocode 9: Design of aluminium structures

EN1991-1-1

EN1991-2

EN1991-1-2

EN1991-3

EN1991-1-3

EN1991-4

EN1991-1-4

EN1991-1-5

EN1991-1-6

EN1991-1-7

EN1991-1-1

EN1991-2

EN1991-1-2

EN1991-3

EN1991-1-3

EN1991-4

EN1991-1-4

EN1991-1-5

EN1991-1-6

EN1991-1-7

**Densities, self weight and
imposed loads**

EN1991-1-1

EN1991-2

EN1991-1-2

EN1991-3

EN1991-1-3

EN1991-4

EN1991-1-4

EN1991-1-5

EN1991-1-6

EN1991-1-7

Snow loads

EN1991-1-1

EN1991-2

EN1991-1-2

EN1991-3

EN1991-1-3

EN1991-4

EN1991-1-4

EN1991-1-5

EN1991-1-6

EN1991-1-7

Wind actions

EN1991-1-1

EN1991-2

EN1991-1-2

EN1991-3

EN1991-1-3

EN1991-4

EN1991-1-4

EN1991-1-5

EN1991-1-6

EN1991-1-7

Thermal actions

EN1991-1-1

EN1991-2

EN1991-1-2

EN1991-3

EN1991-1-3

EN1991-4

EN1991-1-4

EN1991-1-5

EN1991-1-6

EN1991-1-7

Actions during execution

EN1991-1-1

EN1991-2

EN1991-1-2

EN1991-3

EN1991-1-3

EN1991-4

EN1991-1-4

EN1991-1-5

EN1991-1-6

EN1991-1-7

Accidental actions

EN1991-1-1

EN1991-2

EN1991-1-2

EN1991-3

EN1991-1-3

EN1991-4

EN1991-1-4

EN1991-1-5

EN1991-1-6

EN1991-1-7

**Traffic loads on bridges
(Highway and Rail)**

Section	Content
1	General
2	Classification of Actions
3	Design Situations
4	Densities of construction and stored materials
5	Self weight of construction works
6	Imposed loads on buildings
Annex A	Densities and angles of repose of materials
Annex B	Vehicle barriers and parapets for car parks

EN 1990	Eurocode: Basis of structural design
EN 1991	Eurocode 1: Actions on structures
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EN 1994	Eurocode 4: Design of composite 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 for earthquake resistance
EN 1999	Eurocode 9: Design of aluminium structures

General rules and rules for buildings

EN1992-1-1

EN1992-1-2

EN1992-2

EN1992-3

Principal parts required For bridge design

EN1992-1-1

EN1992-1-2

EN1992-2

EN1992-3

General rules and rules for buildings

EN1992-1-1

EN1992-1-2

EN1992-2

EN1992-3

EN1992-1-1

EN1992-1-2

EN1992-2

EN1992-3

Rules for bridges

EN1992-1-1

EN1992-1-2

EN1992-2

EN1992-3

Liquid retaining and containing structures

- Early age thermal effects

- 1 General
 - 2 Basis of Design
 - 3 Materials
 - 4 Durability
 - 5 Structural Analysis
 - 6 Ultimate Limit States
 - 7 Serviceability Limit states
 - 8 Detailing of Reinforcement and Prestressing
 - 9 Detailing of Members and Particular Rules
 - 10 Additional Rules for Precast Concrete Structures
- Cont.

11 Lightweight Aggregate Concrete Structures
12 Plain and Lightly Reinforced Concrete Structures
113 Design for Execution Stages

Annexes A - J; KK - QQ

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 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 for earthquake resistance
EN 1999	Eurocode 9: Design of aluminium structures

EN 1993-1-1

EN 1993-1-11

EN 1993-1-2

EN 1993-1-12

EN 1993-1-3

EN 1993-2

EN 1993-1-4

EN 1993-3-1

EN 1993-1-5

EN 1993-3-2

EN 1993-1-6

EN 1993-4-1

EN 1993-1-7

EN 1993-4-2

EN 1993-1-8

EN 1993-4-3

EN 1993-1-9

EN 1993-5

EN 1993-1-10

EN 1993-6

EN 1993-1-1

EN 1993-1-11

EN 1993-1-2

EN 1993-1-12

EN 1993-1-3

EN 1993-2

EN 1993-1-4

EN 1993-3-1

EN 1993-1-5

EN 1993-3-2

EN 1993-1-6

EN 1993-4-1

EN 1993-1-7

EN 1993-4-2

EN 1993-1-8

EN 1993-4-3

EN 1993-1-9

EN 1993-5

EN 1993-1-10

EN 1993-6

**Principal parts required
for bridge design**

EN 1993-1-1

EN 1993-1-11

EN 1993-1-2

EN 1993-1-12

EN 1993-1-3

EN 1993-2

EN 1993-1-4

EN 1993-3-1

EN 1993-1-5

EN 1993-3-2

EN 1993-1-6

EN 1993-4-1

EN 1993-1-7

EN 1993-4-2

EN 1993-1-8

EN 1993-4-3

EN 1993-1-9

EN 1993-5

EN 1993-1-10

EN 1993-6

General rules and rules for buildings:

Basis of design and partial factors for steel

Material properties

Global analysis

Resistance of cross sections

Buckling

Serviceability

EN 1993-1-1

EN 1993-1-11

EN 1993-1-2

EN 1993-1-12

EN 1993-1-3

EN 1993-2

EN 1993-1-4

EN 1993-3-1

EN 1993-1-5

EN 1993-3-2

EN 1993-1-6

EN 1993-4-1

EN 1993-1-7

EN 1993-4-2

EN 1993-1-8

EN 1993-4-3

EN 1993-1-9

EN 1993-5

EN 1993-1-10

EN 1993-6

Plated structural elements (i.e. steel plates loaded in-plane):

Effective width for global
analysis

Effective width for local
analysis

Stiffened plate design

Shear buckling

Design of stiffeners

Guidance for FE modelling

EN 1993-1-1

EN 1993-1-11

EN 1993-1-2

EN 1993-1-12

EN 1993-1-3

EN 1993-2

EN 1993-1-4

EN 1993-3-1

EN 1993-1-5

EN 1993-3-2

EN 1993-1-6

EN 1993-4-1

EN 1993-1-7

EN 1993-4-2

EN 1993-1-8

EN 1993-4-3

EN 1993-1-9

EN 1993-5

EN 1993-1-10

EN 1993-6

Rules for design of joints

Joint modelling assumptions

Partial safety factors

Bolted and riveted connections

Welded connections

EN 1993-1-1

EN 1993-1-11

EN 1993-1-2

EN 1993-1-12

EN 1993-1-3

EN 1993-2

EN 1993-1-4

EN 1993-3-1

EN 1993-1-5

EN 1993-3-2

EN 1993-1-6

EN 1993-4-1

EN 1993-1-7

EN 1993-4-2

EN 1993-1-8

EN 1993-4-3

EN 1993-1-9

EN 1993-5

EN 1993-1-10

EN 1993-6

Fatigue

Members, connections and
joints

Assessment methods

Determining stresses

Stresses ranges

Fatigue strength

Fatigue verification

EN 1993-1-1

EN 1993-1-11

EN 1993-1-2

EN 1993-1-12

EN 1993-1-3

EN 1993-2

EN 1993-1-4

EN 1993-3-1

EN 1993-1-5

EN 1993-3-2

EN 1993-1-6

EN 1993-4-1

EN 1993-1-7

EN 1993-4-2

EN 1993-1-8

EN 1993-4-3

EN 1993-1-9

EN 1993-5

EN 1993-1-10

EN 1993-6

Material toughness and through thickness properties

Fracture toughness
Lamellar tearing

EN 1993-1-1

EN 1993-1-11

EN 1993-1-2

EN 1993-1-12

EN 1993-1-3

EN 1993-2

EN 1993-1-4

EN 1993-3-1

EN 1993-1-5

EN 1993-3-2

EN 1993-1-6

EN 1993-4-1

EN 1993-1-7

EN 1993-4-2

EN 1993-1-8

EN 1993-4-3

EN 1993-1-9

EN 1993-5

EN 1993-1-10

EN 1993-6

Tension components

Scope: adjustable and
replaceable components

Tension bars

Stay cable

Hangers

Anchors

EN 1993-1-1

EN 1993-1-11

EN 1993-1-2

EN 1993-1-12

EN 1993-1-3

EN 1993-2

EN 1993-1-4

EN 1993-3-1

EN 1993-1-5

EN 1993-3-2

EN 1993-1-6

EN 1993-4-1

EN 1993-1-7

EN 1993-4-2

EN 1993-1-8

EN 1993-4-3

EN 1993-1-9

EN 1993-5

EN 1993-1-10

EN 1993-6

Bridges

Durability

Structural analysis

Performance criteria for bridges

Additional fatigue requirements

Informative technical

specifications for:

- Expansion joints
- Bearings

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 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 for earthquake resistance
EN 1999	Eurocode 9: Design of aluminium structures

EN1994: Steel - concrete composite Structures

EN 1994-1-1

EN 1994-1-2

EN 1994-2

EN1994: Steel - concrete composite Structures

EN 1994-1-1

EN 1994-1-2

EN 1994-2

**General rules and rules for
bridges**

EN1994: Steel - concrete composite Structures

- 1 General
- 2 Basis of Design
- 3 Materials
- 4 Durability
- 5 Structural Analysis
- 6 Ultimate Limit States
- 7 Serviceability Limit states
- 8 Precast concrete slabs in composite bridges
- 9 Composite plates in bridges

EN 1990	Eurocode: Basis of structural design
EN 1991	Eurocode 1: Actions on structures
EN 1992	Eurocode 2: Design of concrete structures
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EN 1998	Eurocode 8: Design for earthquake resistance
EN 1999	Eurocode 9: Design of aluminium structures

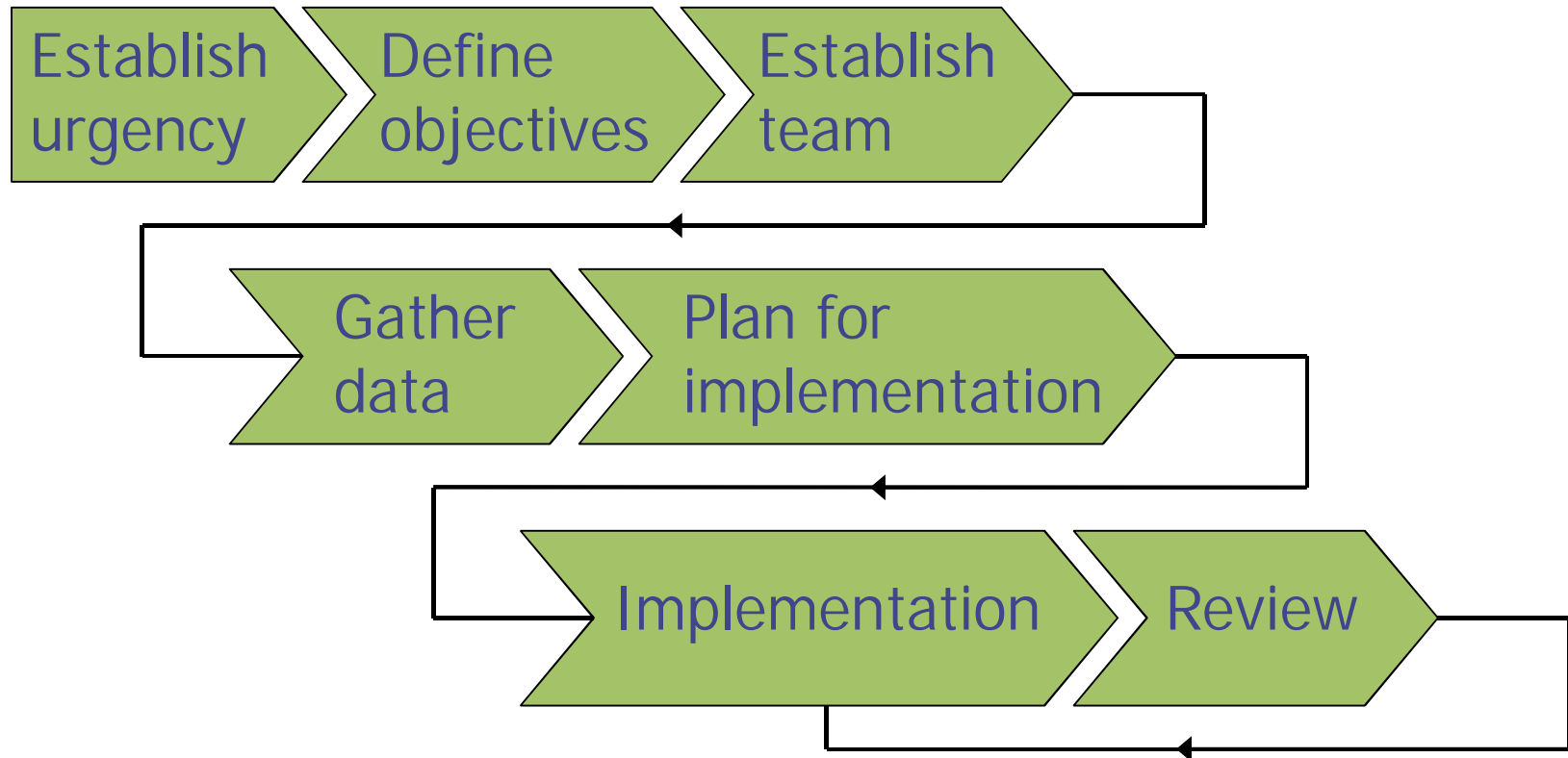
- 1 General
 - 2 Basis of Geotechnical Design
 - 3 Geotechnical Data
 - 4 Supervision of construction, monitoring and maintenance
 - 5 Fill, dewatering, ground improvement and reinforcement
 - 6 Spread foundations
 - 7 Pile foundations
 - 8 Anchorages
- Cont.

9 Retaining structures
10 Hydraulic failure
11 Overall Stability
12 Embankments
Annexes A - J

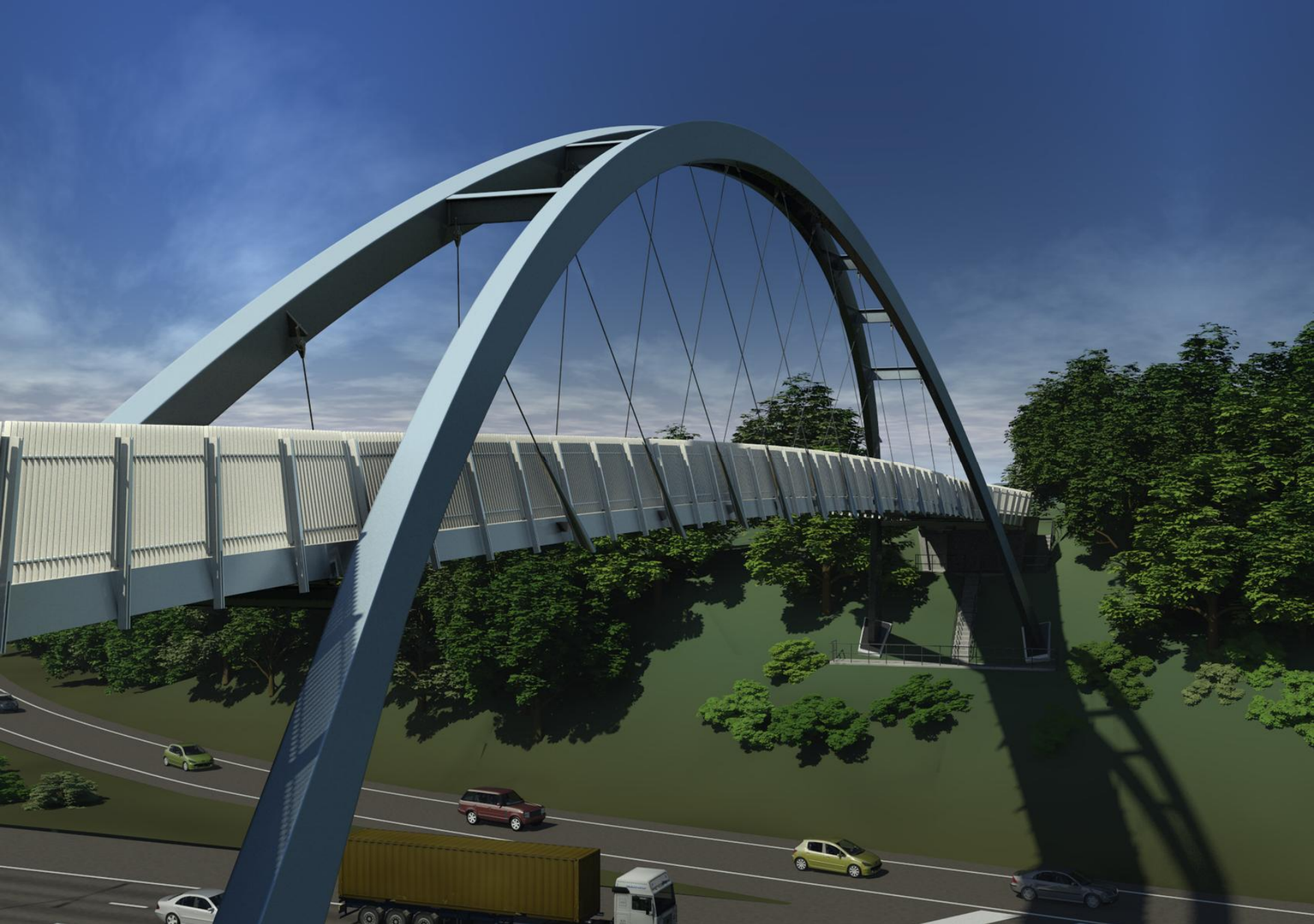
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- Introduction
- Background to the Eurocode Structure
- Overview of the Eurocodes for Bridges
- Experience in design projects
- Conclusions

Implementation Strategy



- Designed by Parsons Brinckerhoff for Devon County Council
- First bridge in UK designed and constructed to complete suit of Eurocodes, National Annexes, National Guidelines and Execution Standards
- Delivered to programme and on budget

























Redhayes Bridge – winner British Construction Industry Award



European
Commission

Seminar 'Bridge Design with Eurocodes' – JRC Ispra, 1-2 October 2012

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Conclusions

- Eurocodes provide comprehensive suite of Standards for bridge design
- Consistent and rational structure
- Focus on principles – providing flexibility for designers
- Application proven by positive experience



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**PARSONS
BRINCKERHOFF**