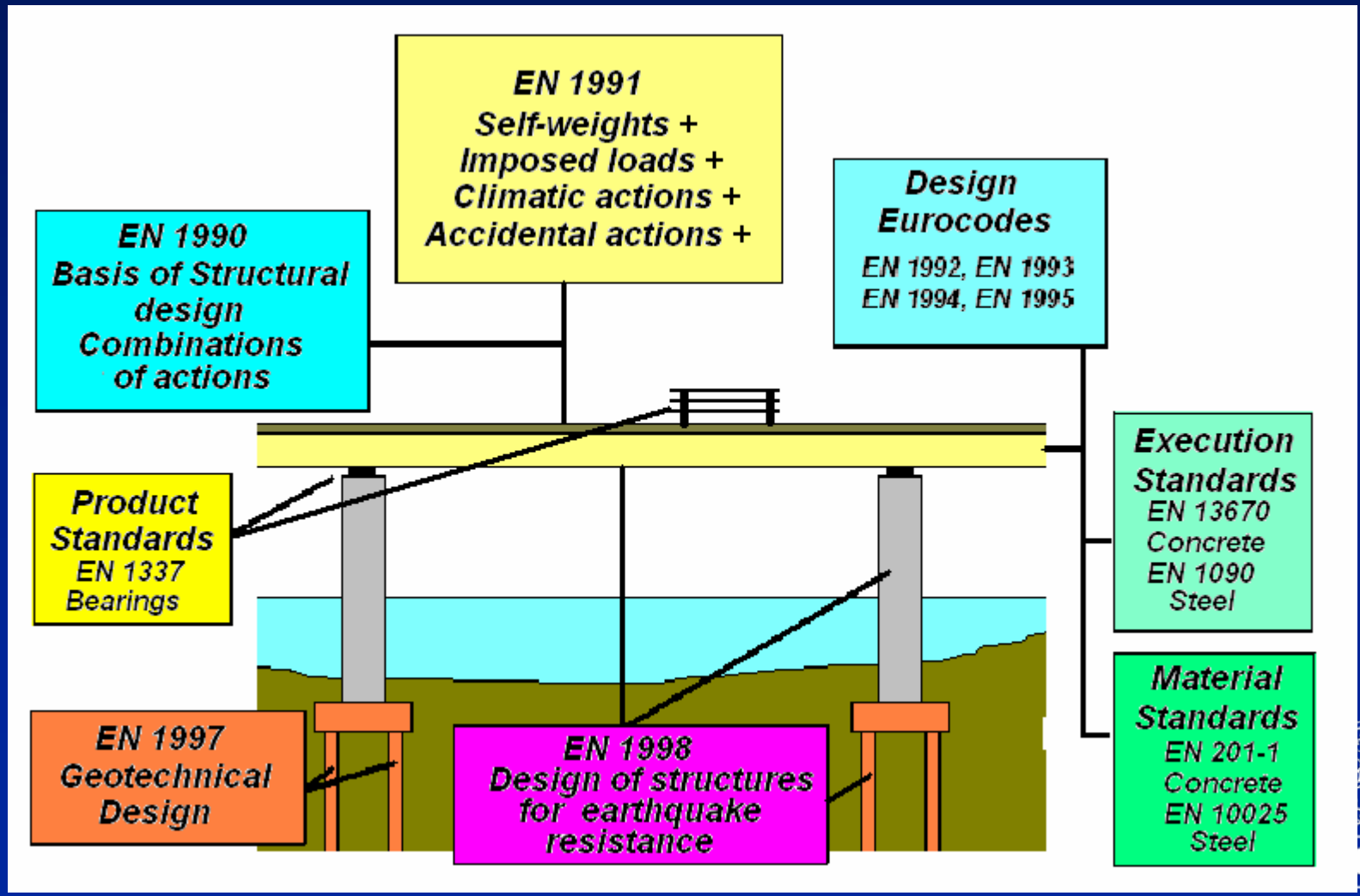
IStructE East Anglia Branch – 31st March 2008

Introduction to the Eurocodes
&
Eurocode 3

Dr David Moore
BCSA

European Standardization



Scope of Presentation

- Objectives of the Eurocodes
- Scope of the Eurocodes
- Eurocode system
- National Annexes
- Implementation of the Eurocodes
- Surprises - Eurocode terminology, symbols & words
- Classification/Cross-sectional resistances
- Publications/Training
- Summary

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Objectives of the Eurocodes and their Status

The European Commission's objective 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"

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The Eurocodes

- 10 sets of design codes with 58 Parts separated into packages
- Packages include buildings, bridges, towers and masts, silos and tanks.
- The head code EN 1990 applies to all types of structures.

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Structural Eurocodes

• EN 1990	Eurocode 0	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 structure for earthquake resistance
• EN 1999	Eurocode 9	Design of aluminium structures

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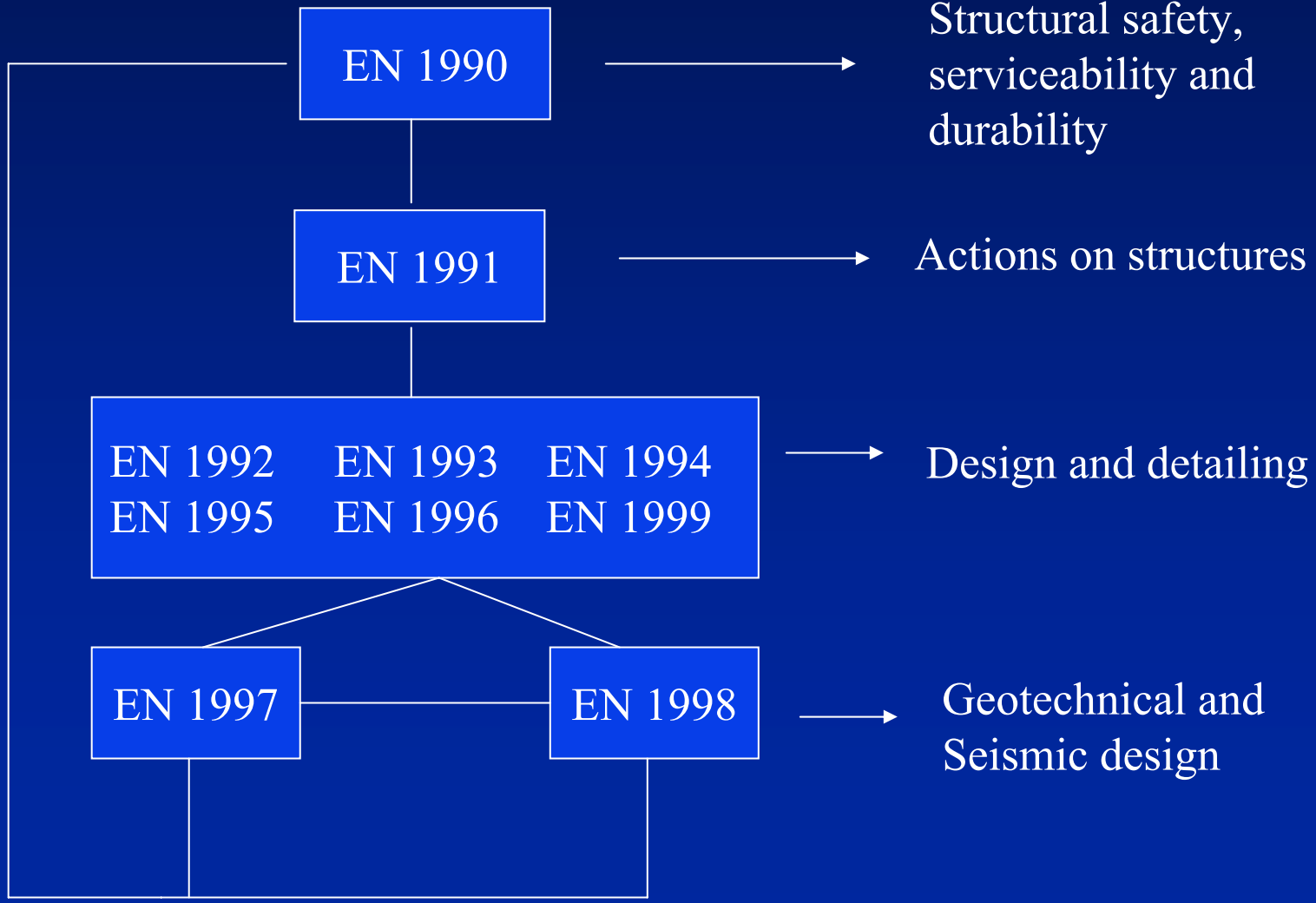
Link between the Eurocodes



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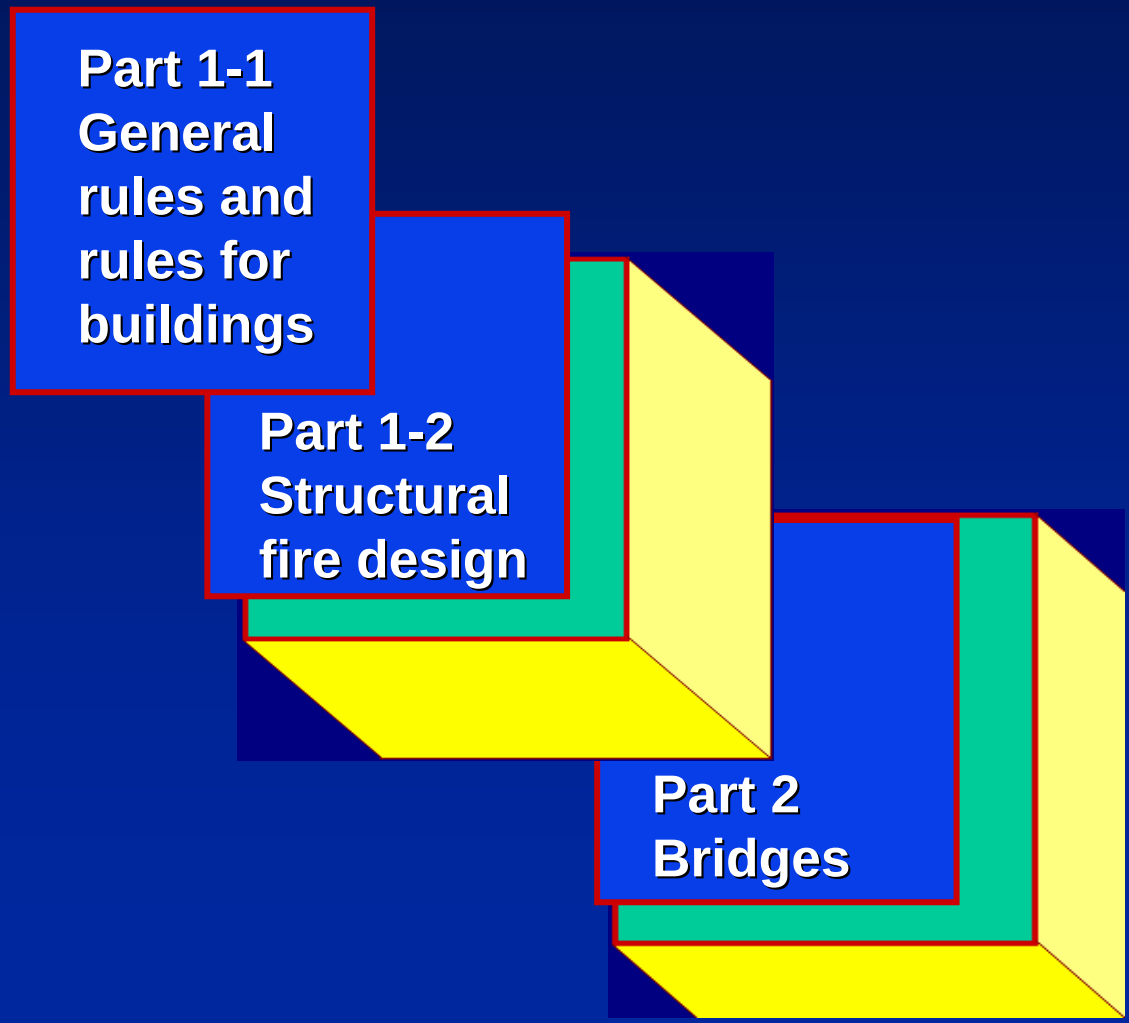
Organisation of design Eurocodes 2, 3, 4, 5 & 8



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Eurocode Design Philosophy

- Limit state design
- Rules validated by reliability
- Clauses are split into Principles and Application rules
- BS5950 concentrates on member design (e.g. beams columns etc), EC concentrates on structural behaviour (e,g, buckling, shear etc).
- The ECs are less codified than the British Standards, with more aspects left open to be determined using first principles.
- Contains National Annex with NDP
- More theory based

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Current Position

- 62 standards published as ENVs or experimental standards
- 58 standards are planned to be published as EN (20 standards on steel structures)

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Earliest date for using the Eurocodes

- All but two standards published by BSI (exceptions are EC3: Part 3.1 and Part 3.2)
- National Annexes available end 2008
- BSI to withdraw conflicting national standards March 2010

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Conflicting National Standards for Eurocode 3

Eurocode	BS to be replaced
BS EN 1993-1-1	BS449, BS5400-3, BS5950-1 BS5950-8
BS EN 1993-1-2	BS5950-8
BS EN 1993-1-3	BS5950-5, BS5950-6 ,BS5950-9
BS EN 1993-1-4	None
BS EN 1993-1-5	BS449, BS5400-3, BS5950-1
BS EN 1993-1-6	None
BS EN 1993-1-7	BS5400-3
BS EN 1993-1-8	BS449, BS4604, BS5400, BS5950-1
BS EN 1993-1-9	BS5950, BS7608
BS EN 1993-1-10	BS449, BS5400-3, BS5950-1
BS EN 1993-1-11	None
BS EN 1993-1-12	None

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Conflicting National Standards for Eurocode 3 cont.

Eurocode	Current BS to be replaced
BS EN 1993-2	BS 5400-3
BS EN 1993-3-1	BS 8110-1,2,3 and 4
BS EN 1993-3-2	BS 4076
BS EN 1993-4-1	None
BS EN 1993-4-2	None
BS EN 1993-4-3	None
BS EN 1993-5	BS 449, BS 5950-1
BS EN 1993-6	BS 449, BS 2853, BS 5950

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National Annexes

“ Eurocodes recognise the responsibility of Regulatory and other Relevant 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 ”

This is through the **National Annex**

National Annexes cont.

- National Annex (NA) only needed if EN Eurocode part is relevant in a country
- Each EN will have a National Foreword that implements the EN through national standards
- The National Annex enables the EN to be used by publishing Nationally Determined Parameters (NDPs)

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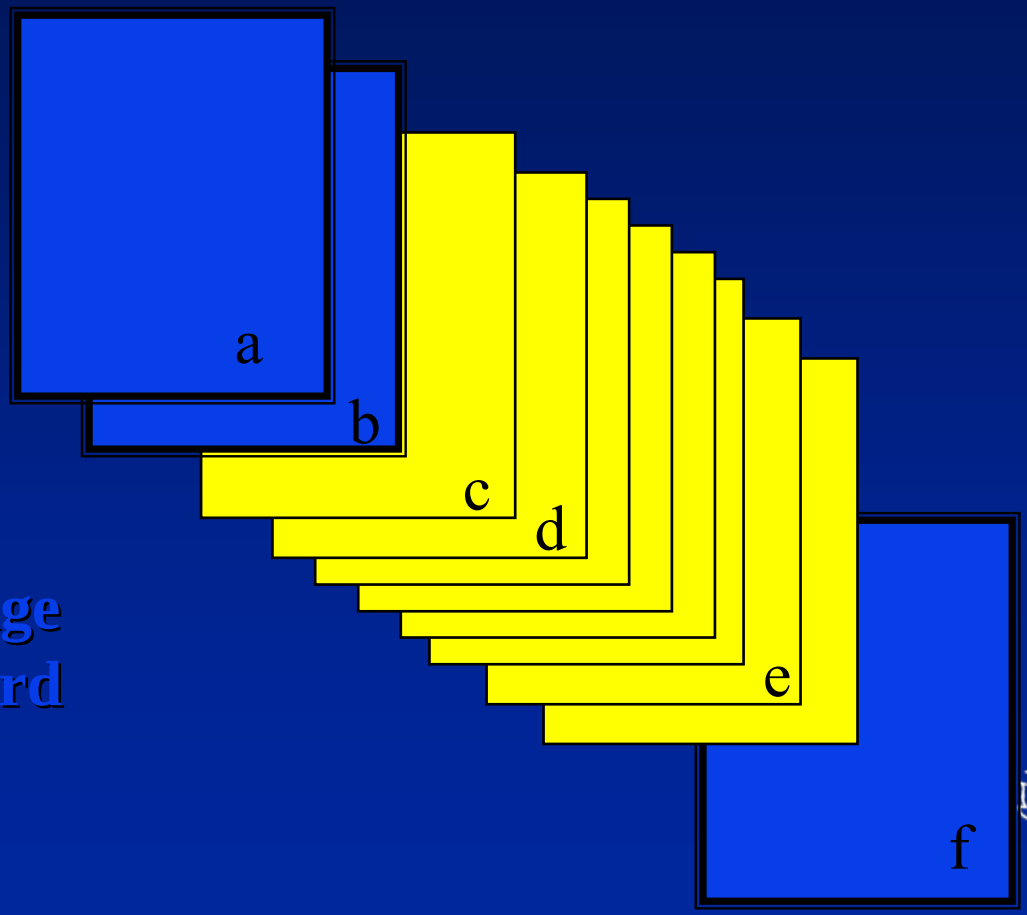
Structural of the Eurocodes



a National title page
b National foreword
c EN title page
d EN text
e EN Annex(es)
f National annex

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Items in a National Annex

- National Annex must be published within 24 months of DAV of EN
- National Annex can only contain items left open by the EN for national choice:
  - Values and/or classes where alternatives are given in EN
  - Values where only a symbol is given in the EN
  - Country specific data (e.g. snow map)
  - Procedure to be used when Eurocode contains alternatives

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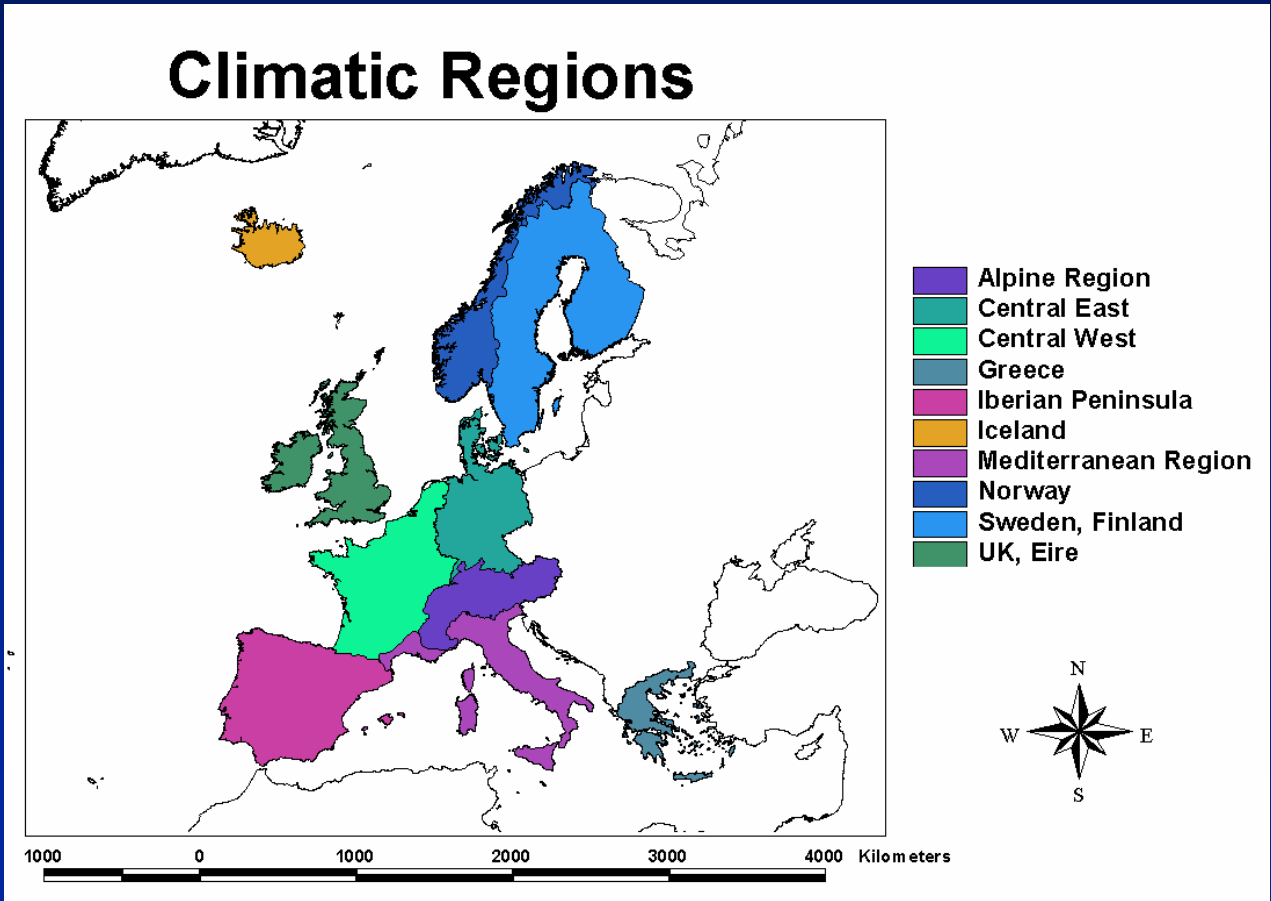
Country Specific Data



Alternative Expressions

Ultimate limit states of STR/GEO - Fundamental combination for persistent and transient design situations

Expression (6.10)

$$\sum_{j\geq 1} \gamma_{G,j} G_{k,j} \text{"+"} \gamma_P P \text{"+"} \gamma_{Q,1} Q_{k,1} \text{"+"} \sum_{i>1} \gamma_{Q,i} \psi_{0,i} Q_{k,i}$$

Expressions (6.10a) and (6.10b)

$$\begin{cases} \sum_{j\geq 1} \gamma_{G,j} G_{k,j} \text{"+"} \gamma_P P \text{"+"} \sum_{i\geq 1} \gamma_{Q,i} \psi_{0,i} Q_{k,i} \\ \sum_{j\geq 1} \xi_j \gamma_{G,j} G_{k,j} \text{"+"} \gamma_P P \text{"+"} \gamma_{Q,1} Q_{k,1} \text{"+"} \sum_{i>1} \gamma_{Q,i} \psi_{0,i} Q_{k,i} \end{cases}$$

$$0{,}85 \leq \xi \leq 1{,}00$$

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Items Not in a National Annex

- Alternative Application Rules
- Amendments to clauses, values or methods
- NA is not a handbook
- No explanations of CEN procedures
- Should not give design guidance
- Interpretation of clauses
- No development of clauses to amplify their use, but references to complementary information are allowed
- NCCI (www.Steel-ncci.co.uk)
- PDs (PD 6688 – Loading; PD 6687 – Concrete etc)

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Other Information in a National Annex

Decision on informative annexes will be made by national competent authority (BSI) and given in NA

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Other Guidance

- The National Annex may have to refer to National (rump) standards. These standards will specify essential guidance not covered in the Eurocode

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Current Position with National Annexes - Loading

The following National Annexes are available:

- NA for EC0 Basis of Structural Design
- NA for EC1: Part 1.1 Densities, Self-weight, and imposed loads
- NA for EC1: Part 1.2 Fire
- NA for EC1: Part 1.3 Snow Load
- NA for EC1: Part 1.5 Thermal actions

All other NAs are in preparation and should be ready by the end of 2008.

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Current Position with National Annexes – Steel & Composite

The following National Annexes will be available in Spring 2008:

- NA for EC3: Part 1.1 – (BCSA, Corus, SCI)
- NA for EC3: Part 1.2 – (BCSA, Corus, SCI)
- NA for EC3: Part 1.8 – (BCSA, Corus, SCI)
- NA for EC3: Part 1.9 – (HA)
- NA for EC3: Part 1.10 – (HA)

- NA for EC4: Part 1.1 – (BCSA, Corus, SCI)
- NA for EC4: Part 1.2 – (BCSA, Corus, SCI)

All other NAs are in preparation and should be ready by the end of 2008.

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Eurocodes required for steel building design
Actions

BS EN 1990	**Basis of structural design**	
BS EN 1991: Part 1.1	**Actions on structures**	**Densities, self-weight and imposed loads**
BS EN 1991: Part 1.2	Actions on structures	Actions on structures exposed to fire
BS EN 1991: Part 1.3	Actions on structures	Snow loads
BS EN 1991: Part 1.4	**Actions on structures**	**Wind actions**
BS EN 1991: Part 1.5	Actions on structures	Thermal actions
BS EN 1991: Part 1.6	Actions on structures	Actions during execution
BS EN 1991: Part 1.7	Actions on structures	Accidental actions
BS EN 1991: Part 3	Actions on structures	Actions induced by cranes and machinery

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Eurocodes required for steel building design
Steel & Composite

BS EN 1993: Part 1.1	**Design of steel structures**	**General rules and rules for buildings**
BS EN 1993: Part 1.2	Design of steel structures	Structural fire design
BS EN 1993: Part 1.5	Design of steel structures	Plated structural elements
BS EN 1993: Part 1.8	Design of steel structures	Design of joints
BS EN 1993: Part 1.10	Design of steel structures	Selection of steel for fracture toughness and through-thickness properties
BS EN 1994: Part 1.1	Design of composite steel and concrete structures – General rules and rules for buildings	
BS EN 1994: Part 1.2	Design of composite steel and concrete structures – General rules and rules for buildings	

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Proposed Changes to Approved Document A

a. Changes in 2008

- References to the Eurocode to be included
- Will be issued for Public Comment
- Needs an impact assessment
- Due Spring 2008

b. Changes in 2010

- Bring the AD in line with Eurocodes
- BS will be removed
- Withdrawn standards will be allowed

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What surprises?

Differences from BS codes

- Axes
- Words
- Symbols
- Gammas everywhere

Different symbols

BS5950	EC3	BS5950	EC3	BS5950	EC3
A	A	P	N	p_y	f_y
Z	W_{el}	M_x	M_y	p_b	χf_y
S	W_{pl}	V	V	p_c	$\chi_{LT} f_y$
I_x	I_y	H	I_w	r	i
I_y	I_z	J	I_t		

Cross-section symbols

b = section breadth

h = section depth

d = depth between fillets (or diameter of CHS)

t_f = flange thickness

t_w = web thickness

r = root radius

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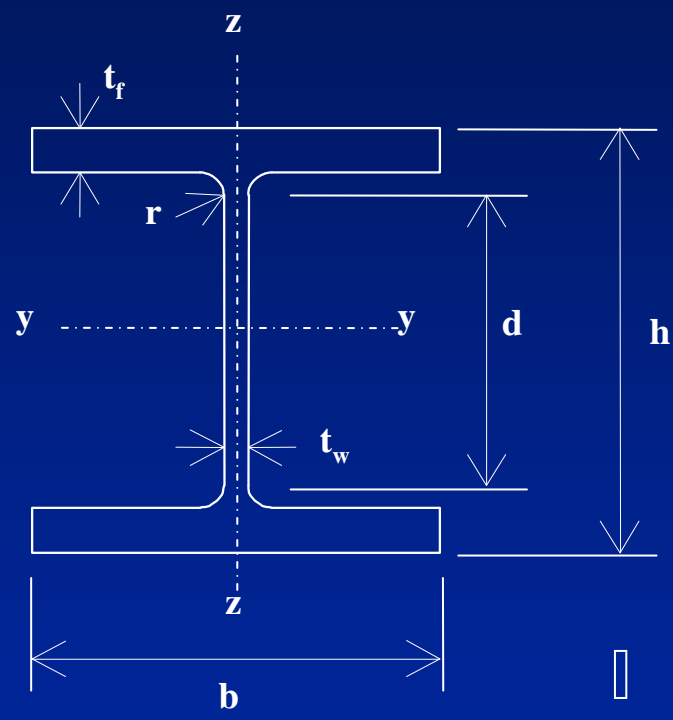
Axes System used in the Eurocodes

- Major axis is y-y
- Vertical axis is z-z
- X direction is along the member

- This is consistent with most FE and Frame analysis Software



EC3 definitions

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Differences between Eurocodes and British Standards

British Standard	**Eurocode**
Force	Action
Capacity (M_c)	Resistance ($M_{c,Rd}$)
Design strength (p_y)	Yield strength (f_y)
Dead load	Permanent load
Live load	Variable load
Wind load	Another variable load

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Change in Values

	BS 5950	Eurocode 3
Load factors	$1.4\ G_k + 1.6Q_k$	$1.35G_k + 1.5\ Q_k$
Load combinations	———	• More combinations • EHF included with every combination
Young's Mod	205,000 N/mm^2	210,000 N/mm^2
Shear Mod.	79000 N/mm^2	81000 N/mm^2

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Gamma M almost everywhere

E.g.: Cross-sectional resistance

$$N_{c.Rd} = A\, f_y / \gamma_{M0}$$

$$M_{c.Rd} = W_{pl}\, f_y / \gamma_{M0}$$

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What does the Eurocode not tell you?

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What is not given?

Examples:

- How to design a column in “simple construction”
- Do purlins restrain rafters and trusses?
- Guidance on effective lengths
- Base stiffness

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Where might we find it?

- National Annex
- Existing guides & BS codes
- New SCI/BCSA/Corus guides
  - Introduction to the Eurocodes
  - Concise Eurocode for steel buildings
  - Resistance tables to EC3
  - Worked examples to EC3
  - Medium rise braced frames to EC3

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Classification

EN 1993-1-1 section 5.5

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ε, epsilon

- Note that in EC3, ε is based on 235 not 275

$$\varepsilon = \sqrt{\frac{235}{f_y}}$$

- in BS 5950,

$$\varepsilon = \sqrt{\frac{275}{p_y}}$$

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Table 5.2 (sheet 1 of 3)

Width, “c”, of compressed element

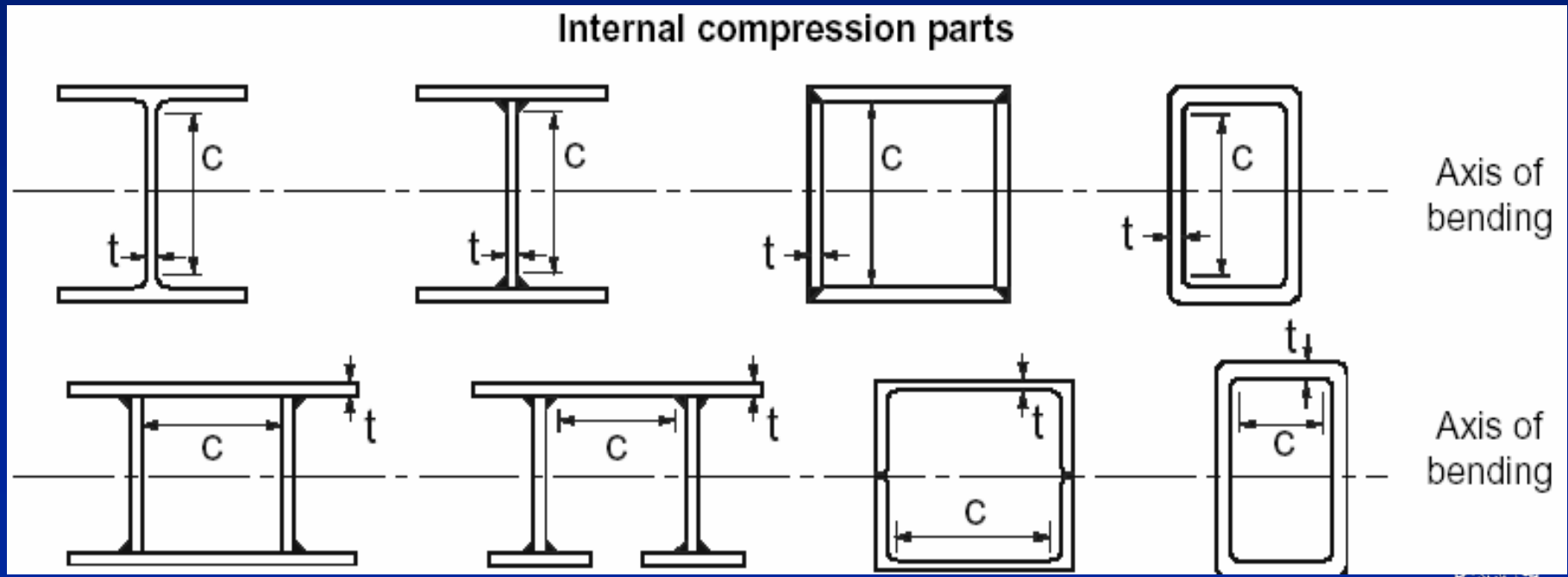
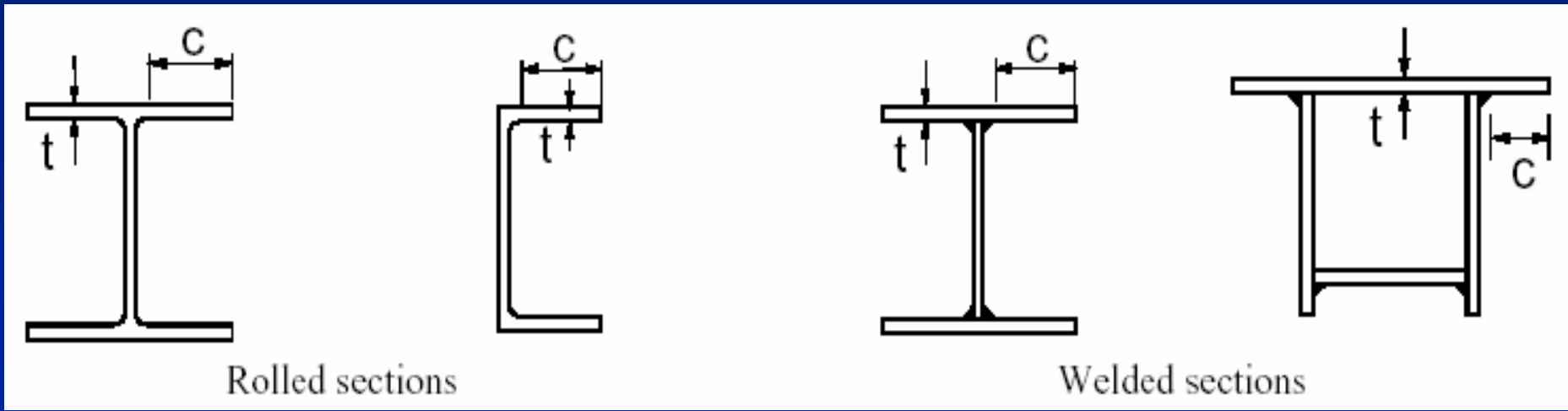


Table 5.2 (sheet 2 of 3)

- Width, “c”, of compressed element



Cross-Sectional Resistance

EN 1993-1-1 section 6.1 & 2

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Gamma M, 6.1

Defined by National Annex

- recommended in EN 1993-1-1 as:

$$\gamma_{M0} = 1{,}0$$

$$\gamma_{M1} = 1{,}0$$

$$\gamma_{M2} = 1{,}25$$

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Very similar to BS 5950-1:2000

- Tension
- Compression
- Shear
  - but some funny looking area formulae
- Bending

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Tension, 6.2.3

- $\frac{N_{Ed}}{N_{t,Rd}} \leq 1,0$
- $N_{t,Rd}$ the lesser of $N_{pl,Rd} = \frac{Af_y}{\gamma_{M0}}$

$$N_{u,Rd} = \frac{0,9A_{net}f_u}{\gamma_{M2}}$$

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Compression, 6.2.4

- $$\frac{N_{Ed}}{N_{c,Rd}} \leq 1{,}0$$
- Class 1, 2, 3 $$N_{c,Rd} = \frac{A f_y}{\gamma_{M0}}$$
- Class 4 $$N_{c,Rd} = \frac{A_{eff} f_y}{\gamma_{M0}}$$

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Bending, 6.2.5

- $$\frac{M_{Ed}}{M_{c,Rd}} \leq 1{,}0$$
- Class 1, 2 $$M_{c,Rd} = M_{pl,Rd} = \frac{W_{pl} f_y}{\gamma_{M0}}$$
- Class 3 $$M_{c,Rd} = M_{el,Rd} = \frac{W_{el,min} f_y}{\gamma_{M0}}$$
- Class 4 $$M_{c,Rd} = \frac{W_{eff,min} f_y}{\gamma_{M0}}$$

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Shear, 6.2.6

$$\frac{V_{Ed}}{V_{c,Rd}} \leq 1{,}0$$

- For plastic shear resistance

$$V_{c,Rd} = V_{pl,Rd} = \frac{A_v\left(f_y / \sqrt{3}\right)}{\gamma_{M0}}$$

- Check for shear buckling if

$$\frac{h_w}{t_w} > 72\frac{\varepsilon}{\eta}$$

for η see EN 1993-1-5, may safely take 1.0

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Economic Effects

- Design costs initially may be slightly more due to unfamiliarity of the codes and more complex analysis
- Over a period of time the cost are expected to be similar
- Material costs ?

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Eurocode Design Guides

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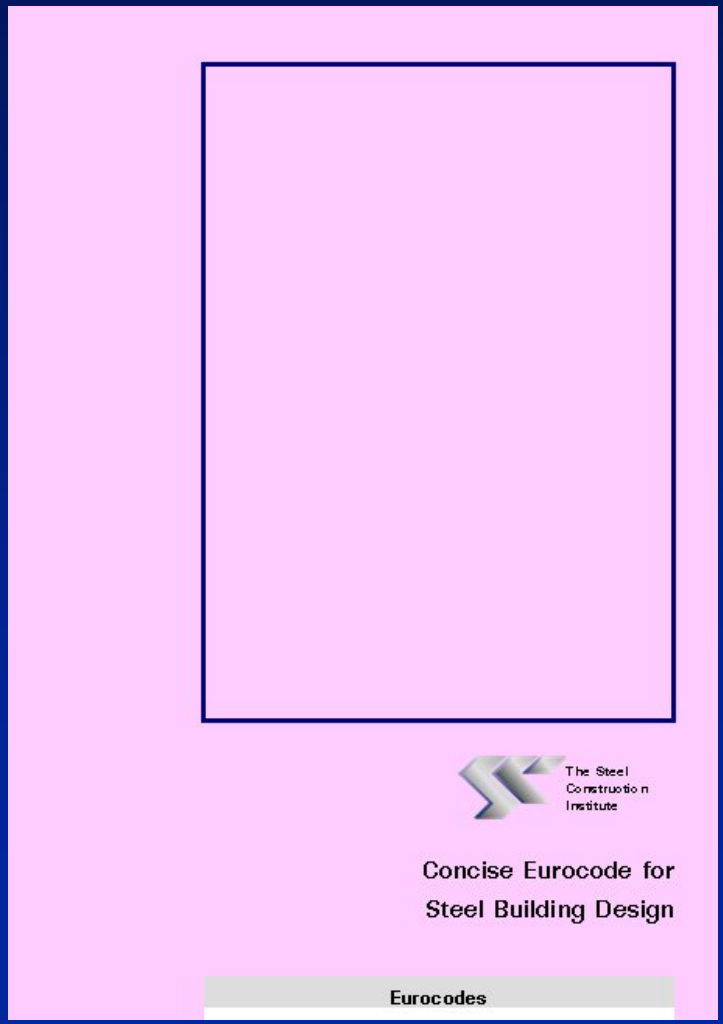
Forthcoming BCSA/SCI Design Guides



- Introduction to the Eurocodes
- Concise Eurocode for Steel Building Design
- Section Properties and Member Resistances
- Member Worked Examples – Steel
- Design of Medium Rise Steel-Frame Building
- Blue book (Burgundy book)
- Red book
- Simple connections
- Moment Connections
- NSSS (updated to align with EN 1090-2)
- Bridge publications

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Eurocode Training

- Eurocode course already available from SCI (See www.steel-sci.org/courses)
- BCSA/TWI event on execution to EN 1090-2
- Corus events across the UK in 2008
- Eurocode expert (www.eurocodes.co.uk)
- Access-steel (www.access-steel.com)
  - Worked examples
  - Tedds Lite examples
  - Case studies
  - Harmonised guidance on steel design

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Summary

- The Eurocodes are coming
- A National Annex is need before a Eurocode can be used in the UK
- 58 parts – 23 are Steel and Composite
- Available end of 2008
- National Standards withdrawn in 2010
- Rationalises, design and terminology across all materials and countries
- The European region is 10 times bigger than the UK
- Design guides will be available 2008
- Companies need to develop a strategy to implement the Eurocodes over a period of 2 to 3 years

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Introduction to the Eurocodes

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Eurocodes required for steel building design - Actions

BS EN 1990		
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BS EN 1991: Part 1.7	Actions on structures	Accidental actions
BS EN 1991: Part 3	Actions on structures	Actions induced by cranes and machinery

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Differences between Eurocode and British Standard

	British Standard	Eurocode
Elastic Modulus	Z	W_{el}
Plastic Modulus	S	W_{pl}
Radius of gyration	r	i
Torsion constant	J	I_t
Warping constant	H	I_w

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Eurocode 3 – Moment Resistance

BS 5950	**Eurocode 3**
• Class 1 and 2 $M_C = p_Y S$	• Class 1 and 2 $M_{c,Rd} = f_y W_{pl} / \gamma_{M0}$
• Class 3 semi-compact $M_c = p_Y Z$ or $M_c = p_Y S_{eff}$	Class 3 $M_{c,Rd} = f_y W_{el,min} / \gamma_{M0}$
• Class 4 slender $M_c = p_Y Z_{eff}$	• Class 4 $M_{c,Rd} = f_y W_{eff,min} / \gamma_{M0}$
• Low shear $F_v < 60\% P_v$	• Low shear $V_{Ed} < 50\% V_{pl,Rd}$

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