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Structural Steel and Timber Design SAB3233

Topic 4
Design of steel structures (BS EN 1993)

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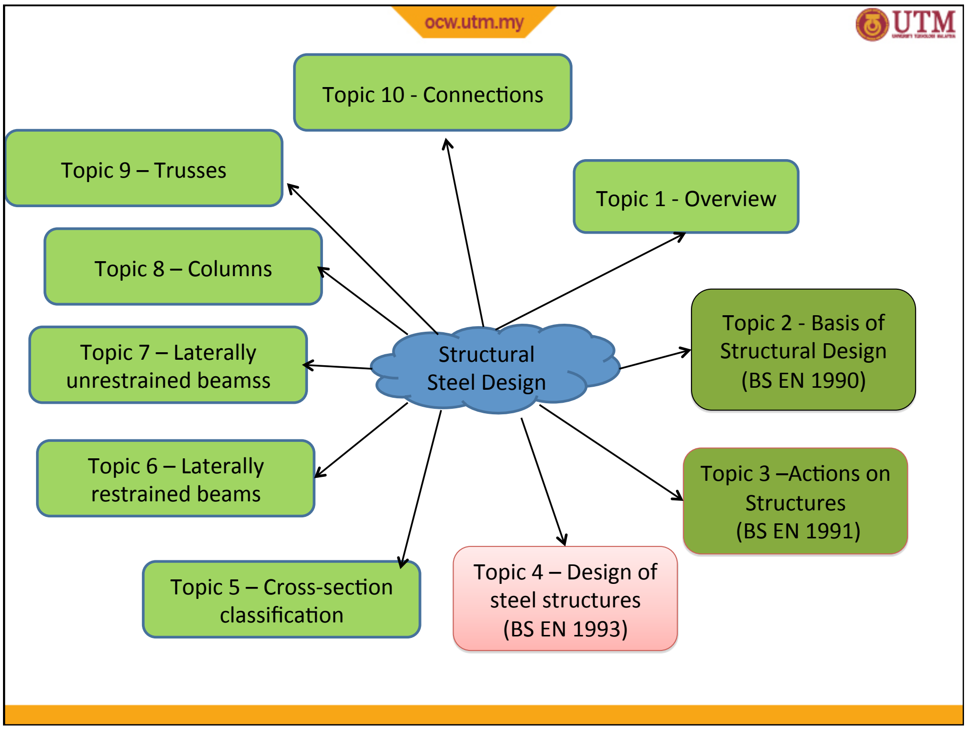

Structural Eurocodes- an overview

BS EN 1990, Eurocode
Basis of Structural Design

Structural safety, serviceability and durability

BS EN 1991, Eurocode 1
Actions on Structures

Actions on structures

BS EN 1992, Eurocode 2: Concrete
BS EN 1993, Eurocode 3: Steel
BS EN 1994, Eurocode 4: Composite
BS EN 1995, Eurocode 5: Timber
BS EN 1996, Eurocode 6: Masonry
BS EN 1999, Eurocode 9: Aluminium

Design and detailing

BS EN 1997, Eurocode 7
Geotechnical design

BS EN 1998, Eurocode 8
Seismic design

Geotechnical and seismic design

3

Eurocode 3: Design of steel structures –

Part 1-1: General rules and rules for Buildings
BS EN 1993-1-1:2005

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Eurocode 3 : Content

- 5. Structural analysis
  - 5.1 Structural modelling for analysis
    - 5.1.1 Structural modelling and basic assumptions
    - 5.1.2 Joint modelling
    - 5.1.3 Ground-structure interaction
  - 5.2 Global analysis
    - 5.2.1 Effects of deformed geometry of the structure
    - 5.2.2 Structural stability of frames
  - 5.3 Imperfections
    - 5.3.1 Basis
    - 5.3.2 Imperfections for global analysis of frames
    - 5.3.3 Imperfection for analysis of bracing systems
    - 5.3.4 Member imperfections
  - 5.4 Methods of analysis considering material non-linearities
    - 5.4.1 General
    - 5.4.2 Elastic global analysis
    - 5.4.3 Plastic global analysis
  - 5.5 Classification of cross sections
    - 5.5.1 Basis
    - 5.5.2 Classification
  - 5.6 Cross-section requirements for plastic global analysis

5

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6

Eurocode 3 : Content

- 6. Ultimate limit states
  - *6.1 General*
  - *6.2 Resistance of cross-sections*
    - 6.2.1 General
    - 6.2.2 Section properties
    - 6.2.3 Tension
    - 6.2.4 Compression
    - 6.2.5 Bending moment
    - 6.2.6 Shear
    - 6.2.7 Torsion
    - 6.2.8 Bending and shear
    - 6.2.9 Bending and axial force
    - 6.2.10 Bending, shear and axial force
  - *6.3 Buckling resistance of members*
    - 6.3.1 Uniform members in compression
    - 6.3.2 Uniform members in bending
    - 6.3.3 Uniform members in bending and axial compression
    - 6.3.4 General method for lateral and lateral torsional buckling of structural components.
    - 6.3.5 Lateral torsional buckling of members with plastic hinges
  - *6.4 Uniform built-up compression members*
    - 6.4.1 General
    - 6.4.2 Laced compression members
    - 6.4.3 Battened compression members
    - 6.4.4 Closely spaced built-up members

7

Eurocode 3 : Content

- 7. Serviceability limit states
  - *7.1 General*
  - *7.2 Serviceability limit states for buildings*
    - 7.2.1 Vertical deflections
    - 7.2.2 Horizontal deflections
    - 7.2.3 Dynamic effects

- Annex
  - Annex A [informative] – Method 1: Interaction factors kij for interaction formula in 6.3.3(4)
  - Annex B [informative] – Method 2: Interaction factors kij for interaction formula in 6.3.3(4)
  - Annex AB [informative] – Additional design provisions
  - Annex BB [informative] – Buckling of components of building structures

8

- the principles of design, concept and formulation are generally similar to BS5950
- the main differences of the two design rules are only in the symbols, terms, safety factors and limits adopted
- distinction is made between
  - principles which must be obeyed
  - application rules which follow the principles but alternative methods are allowed
- design capacities in EC3 are categorised under cross-section resistance and member buckling resistance (based on structural behaviour and not based on element/member)

- based on limit state design principles which require that specific 'failure' conditions must be checked for both ultimate and serviceability conditions
- variability, principally of actions and materials, is accounted for by partial safety factors which also incorporate a global margin of safety
- EC3 incorporates theories in the first-order and second order which consider the effects of deformations
- EC3 allows us to choose the degree of accuracy of the structural analysis
- allows for the "advanced analysis approach" in analysis and design as an alternative to simplified design method

- frame imperfection(P-D and P-d effect) to be included in the structural modeling of frames
- a comprehensive information on the elastic-perfectly plastic and elasto-plastic methods for continuous and semi-continuous steel framing
- providing classification of the connections based on strength and rigidity
- the information on frame stability is presented in detailed whilst the terms sway and non-sway frames are well defined

Distinction between principles and application rules

(1) The Principles comprise :
   - general statements and definitions for which there is no alternative
   - requirements and analytical models for which no alternative is permitted

(2) The Principles are identified by the letter P following the paragraph number.

(3) The Application Rules are generally recognised rules which comply with the Principles and satisfy their requirements.

(4) It is permissible to use alternative design rules different from the application Rules given in EN 1990 for works, provided that it is shown that the alternative rules accord with the relevant Principles and are at least equivalent with regard to the structural safety, serviceability and durability which would be expected when using the Eurocodes.

2.1 Requirements

(1) P The design of steel structures shall be in accordance with the general rules given in EN 1990.

2.2 Principles of limit state design

Limit states - states beyond which the structure no longer fulfils the relevant design criteria

Ultimate limit states – states associated with collapse or with other similar forms of structural failure. Ultimate limit state, concerned with 'collapse' like yielding, buckling and overturning.

The following conditions should be considered:

1. Stability: overturning (equilibrium)
2. Strength: including local and overall buckling effects where appropriate

Serviceability limit states – states that correspond to conditions beyond which specified service requirements for a structure or structural member are no longer met. Serviceability limit state, concerned with 'function': like deflection and vibration.

Both conditions are associated with stiffness rather than strength. For most buildings, controlling deflections will also limit vibrations

Partial safety factors are applied to characteristic values to obtain design values

Suffices k and d are used to signify characteristic and design values respectively

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Load combinations can be simplified as:

1,35 Gk + 1,5 Qk	where Qk is the dominant imposed load, and
1,35 Gk + 1,35Qk	where there are more than one imposed loads

Where loads have a beneficial effect: 0.9 Gk

SLS

Load combinations can be simplified as:

1,0 Gk + 1,0 Qk	where Qk is the dominant imposed load, and
1,0 Gk + 0,9 Qk	where there are more than one imposed loads

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Analyse using appropriate methods and accounting for variability to determine:

1. Design effects {E}, and
2. Design resistance {R}

Ensure no limit state is exceeded {R > E}

Eurocode 3 – Design Checks

- Design checks are required and it depends on the type of structure
- Frames are checked for
  - Static equilibrium
  - Frame stability
  - Resistance of cross-sections
  - Resistance of members
  - Resistance of joints
- Tension members need only checked for resistance of cross-sections

2.3 Basic variables

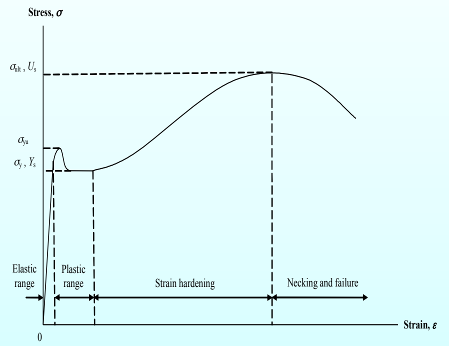
2.3.1 Actions and environmental influences

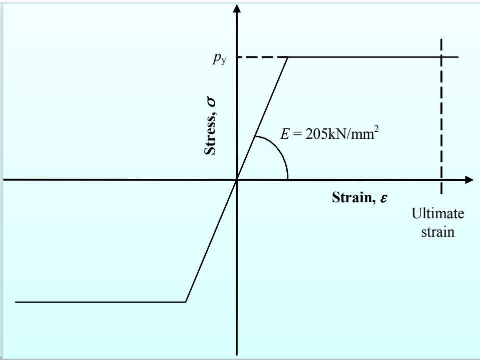
2.3.2 Material and product properties

Material properties

- 3 nominal grades of steel (EN 10 025):
  - Fe 360 nominal strength =235 N/mm^2
  - Fe 430 nominal strength =275 N/mm^2
  - Fe 510 nominal strength =355 N/mm^2
- Strengths reduce for t>40mm and 100mm
- For all steels E = 210 kN/mm^2

Properties of Steel
Yield Strength f_y





Typical stress-strain curve for structural mild steel obtained from a tensile test

Idealized stress-strain curve of BS 5950

Eurocode 3

3. Materials – yield strength- hot rolled

Nominal values of yield strength f_y and ultimate tensile strength f_u for hot rolled structural steel

Standard and steel grade	Nominal thickness of the element t [mm]			
	$t \leq 40$ mm		40 mm $< t \leq 80$ mm	
	f_y [N/mm²]	f_u [N/mm²]	f_y [N/mm²]	f_u [N/mm²]
EN 10025-2				
S 235	235	360	215	360
S 275	275	430	255	410
S 355	355	510	335	470
S 450	440	550	410	550
EN 10025-3				
S 275 N/NL	275	390	255	370
S 355 N/NL	355	490	335	470
S 420 N/NL	420	520	390	520
S 460 N/NL	460	540	430	540
EN 10025-4				
S 275 M/ML	275	370	255	360
S 355 M/ML	355	470	335	450
S 420 M/ML	420	520	390	500
S 460 M/ML	460	540	430	530

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3. Materials – Yield strentgh

Steel grade	EN 1993-1-1	
	Thickness range (mm)	Yield strength, f_y
S235	$t \leq 40$	235
	$40 < t \leq 80$	215
S275	$t \leq 40$	275
	$40 < t \leq 80$	255
S355	$t \leq 40$	355
	$40 < t \leq 80$	335

For more detail of material properties, refer to Table 3.1

Eurocode 3

3. Materials – yield strength- hot rolled

Nominal values of yield strength f_y and ultimate tensile strength f_u for hot rolled structural steel

Standard and steel grade	Nominal thickness of the element t [mm]			
	t ≤ 40 mm		40 mm < t ≤ 80 mm	
	f_y [N/mm²]	f_u [N/mm²]	f_y [N/mm²]	f_u [N/mm²]
EN 10025-2				
S 235	235	360	215	360
S 275	275	430	255	410
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S 450	440	550	410	550
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EN 10025-4				
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S 355 M/ML	355	470	335	450
S 420 M/ML	420	520	390	500
S 460 M/ML	460	540	430	530

Eurocode 3

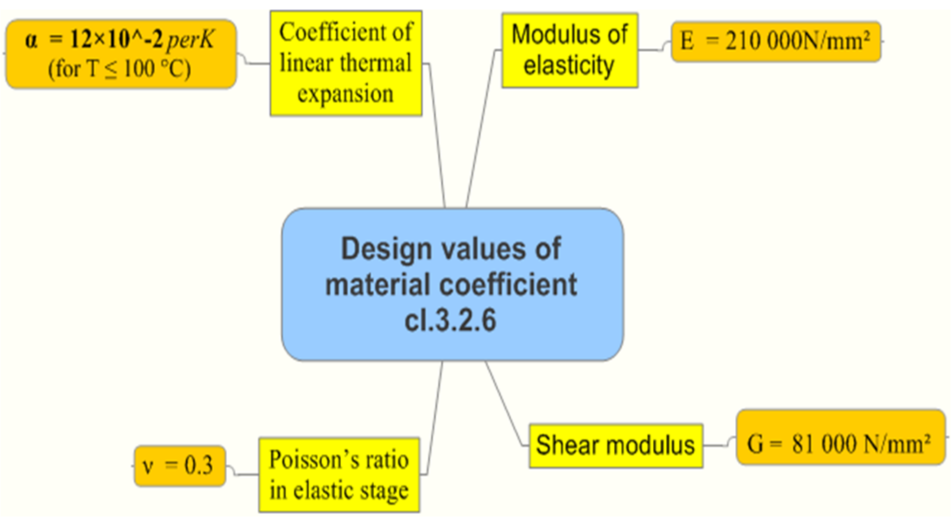
3. Materials - yield strength- SHS

(continued): Nominal values of yield strength f_y and ultimate tensile strength f_u for structural hollow sections

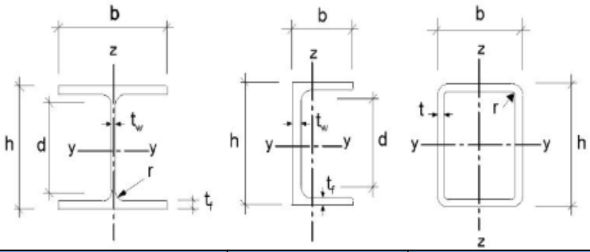
Standard and steel grade	Nominal thickness of the element t [mm]			
	t ≤ 40 mm		40 mm < t ≤ 80 mm	
	f_y [N/mm²]	f_u [N/mm²]	f_y [N/mm²]	f_u [N/mm²]
EN 10210-1				
S 235 H	235	360	215	340
S 275 H	275	430	255	410
S 355 H	355	510	335	490
S 275 NH/NLH	275	390	255	370
S 355 NH/NLH	355	490	335	470
S 420 NH/NHL	420	540	390	520
S 460 NH/NLH	460	560	430	550

3.2 Structural steel - material properties

- modulus of elasticity $E = 210\,000\ N/mm^2$
- shear modulus $G = \frac{E}{2(1+\nu)} \approx 81\,000\ N/mm^2$
- Poisson's ratio in elastic stage $\nu = 0,3$
- coefficient of linear thermal expansion $\alpha = 12 \times 10^{-6}\ perK$ (for $T \le 100\ °C$)



Section Properties



	EC	BS 5950
Major axis	y-y	x-x
Minor axis	z-z	y-y
Along the member	x-x	-
Elastic modulus	W_{el}	Z
Plastic modulus	W_{pl}	S
Yield strength	f_y	P_y
	3,456	3.456

Thank You