Steel structures I

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- Structural design
- Design methods
- Euro code

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- Working and factored loads
- Stability limit states
- Structural integrity
- Serviceability limit state deflection
- Design strength of materials
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Steel structures I

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- Section properties

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- Types and uses
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- Classification of beam cross-sections
- Bending stresses and moment capacity
- Lateral torsional buckling
- Shear in beams
- Deflection of beams
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Steel structures I

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Steel structures I

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STEEL STRUCTURES I

Introduction

Steel is most often used for structures where loads and spans are large and therefore is not often used for domestic architecture.

Steel structures include:

- ❑- low-rise and high-rise buildings,
- ❑- bridges,
- ❑- towers,
- ❑- pylons,
- ❑- floors,
- ❑- oil rigs, etc.

and are essentially composed of frames which support the self-weight, dead loads and external imposed loads (wind, snow, traffic, etc.)

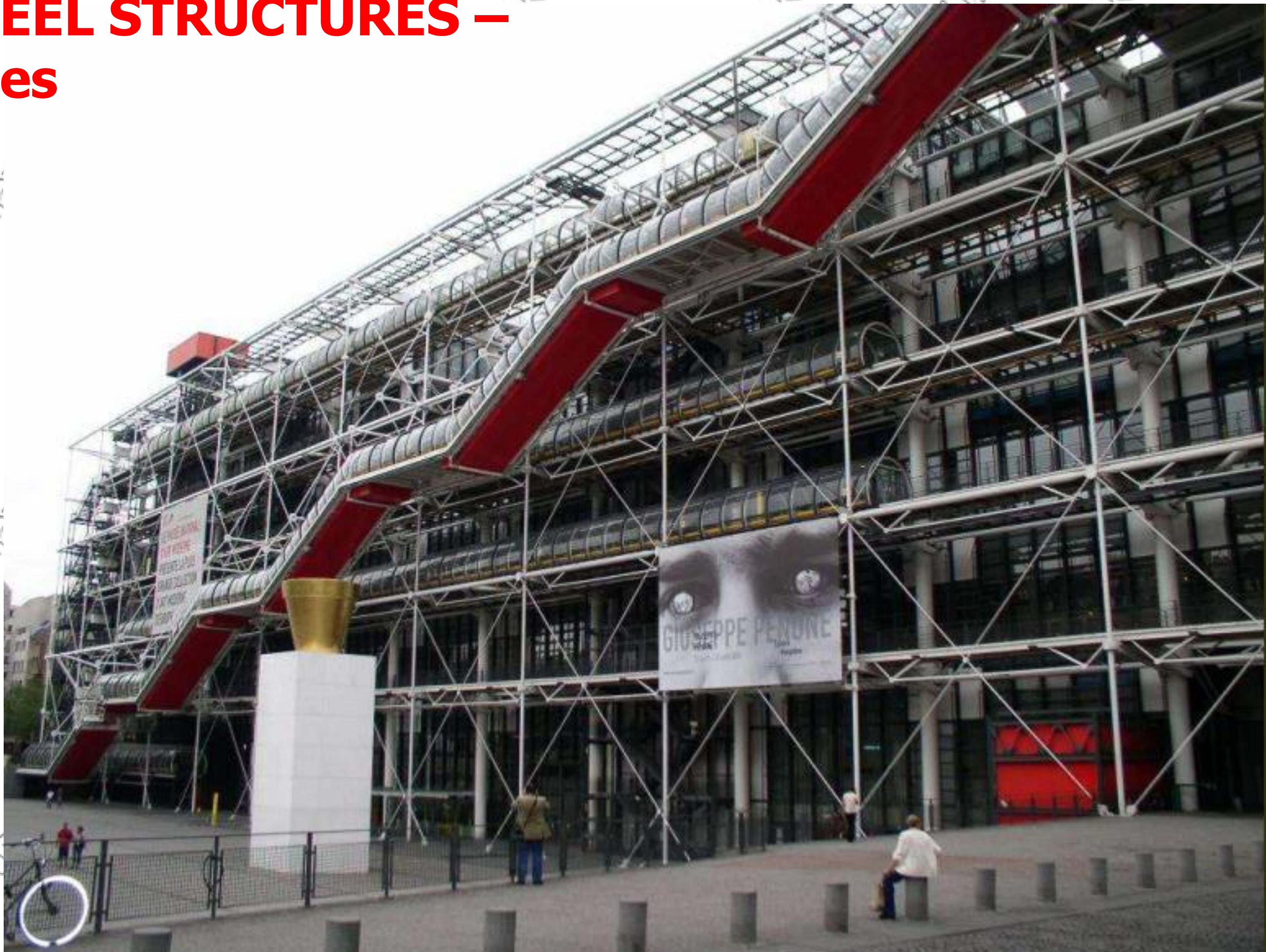
STEEL STRUCTURES – Uses

Single story building-
Industrial building-
Portal frame system

STEEL STRUCTURES – Uses

Single story building- Industrial building- Truss system

STEEL STRUCTURES – Uses



Multi story building: the Pompidou center- Paris

STEEL STRUCTURES – Uses

Precast hollow core concrete planks are the floor system in this steel structure

STEEL STRUCTURES – Uses

parking garage

STEEL STRUCTURES – Uses

Chicago airport terminal building.

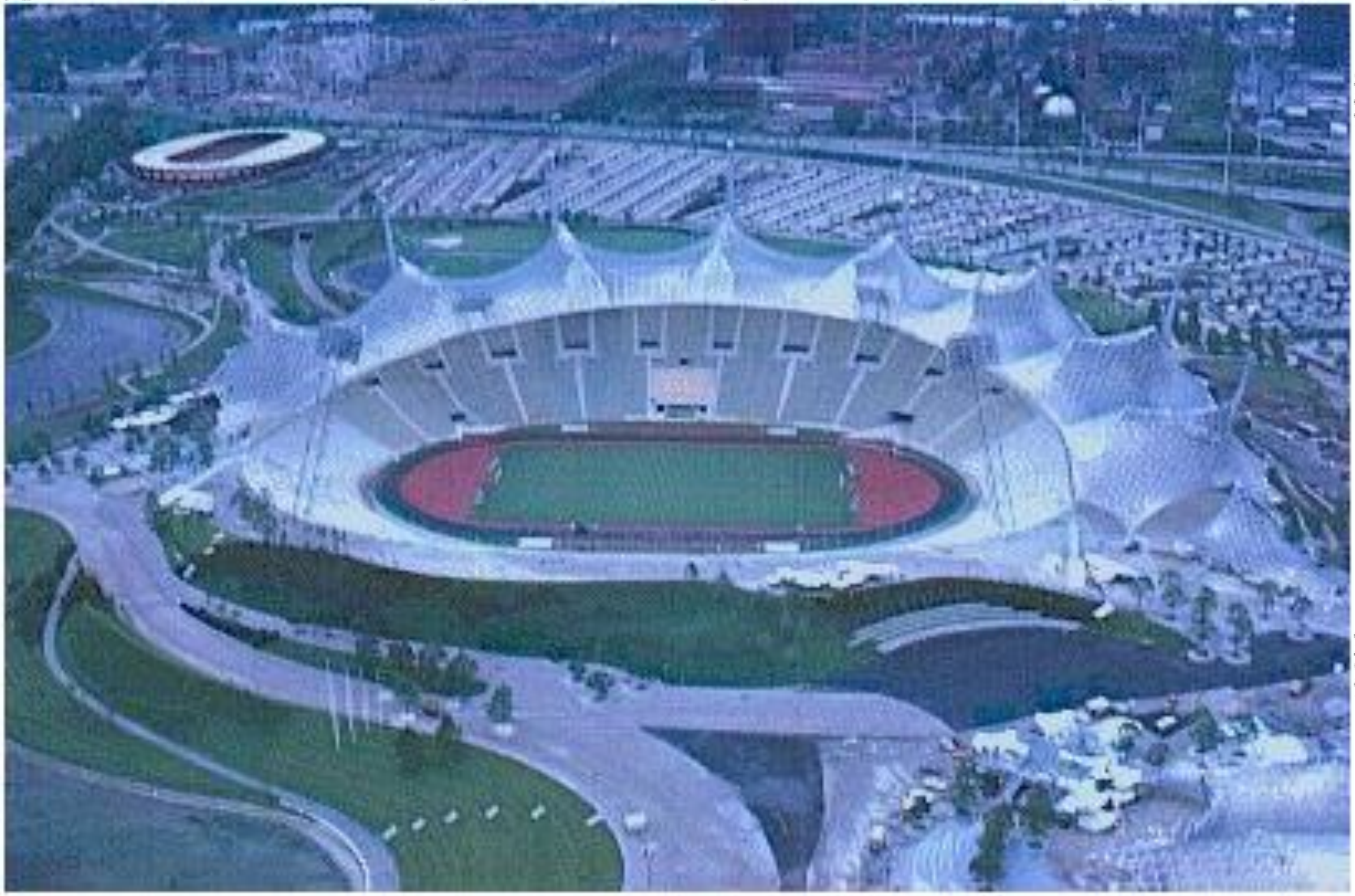
STEEL STRUCTURES – Uses

Open corner entrance to this office building was met by the use of two-story-high trusses.

STEEL STRUCTURES – Uses

Sky-scraper in Dubai

STEEL STRUCTURES – Uses



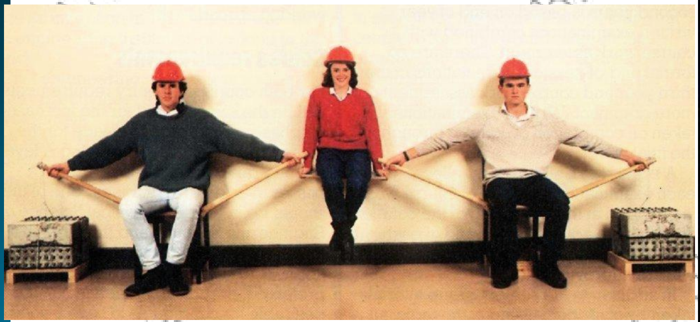
Olympic Stadium, Munich, Germany

STEEL STRUCTURES – Uses

Space-frame roof

STEEL STRUCTURES – Uses

The Forth Bridge-Scotland



Pont du Normandie (River Seine, Le Harve, France)

STEEL STRUCTURES – Uses

Golden Gate

Sydney Harbor Arch Bridge

STEEL STRUCTURES – Uses

North Sea Oil Platform

STEEL STRUCTURES – Uses

Strengthening works

STEEL STRUCTURES

Introduction

The advantages

1- speed of construction :

Steel provides unbeatable speed of construction and off-site fabrication, there by reducing the financial risks associated with site-dependent delays.

2- high strength, high stiffness and good ductility :

steel construction, with its high strength to weight ratio, maximizes the useable area of a structure and minimizes self-weight, again resulting in cost savings.

3- Recycling

Recycling and reuse of steel also mean that steel construction is well-placed to contribute towards reduction of the environmental impacts of the construction sector.

4- high accuracy

Disadvantages

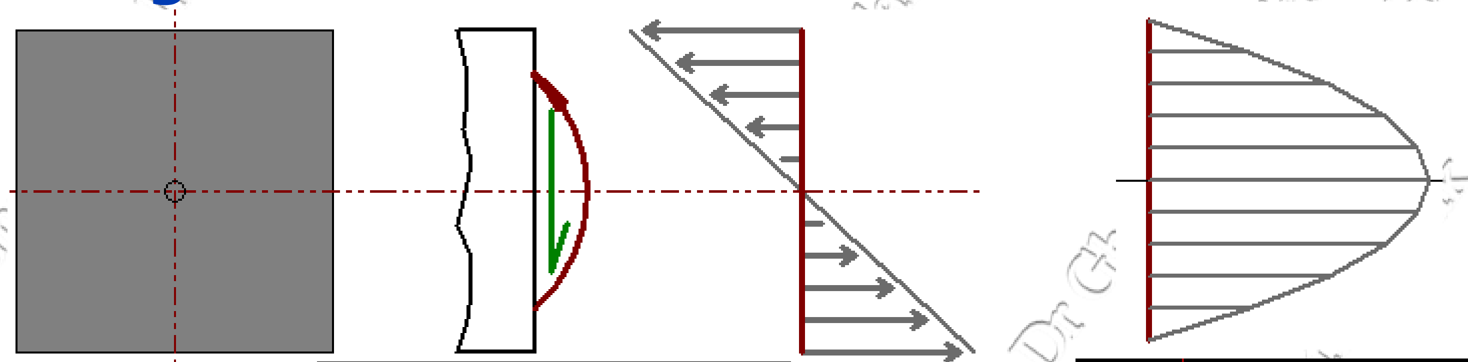
1- low fire resistance
2- needs of higher educated personal

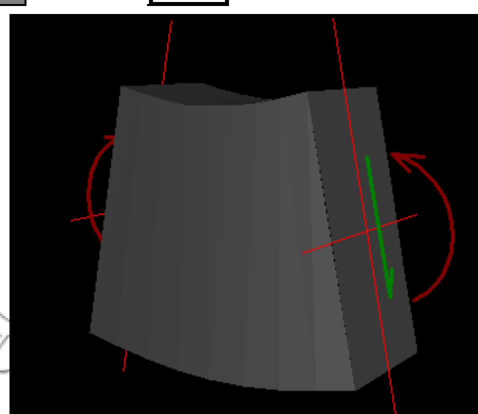
STEEL STRUCTURES

STRUCTURAL ELEMENTS

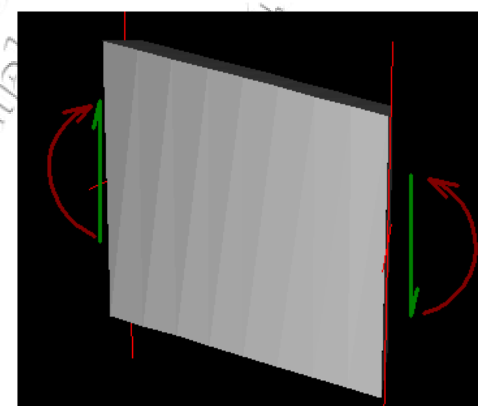
As mentioned earlier, steel Structures are composed of distinct elements:

1. *Beams and girders*: members carrying lateral loads in **bending** and **shear**.





Showing bending deformation

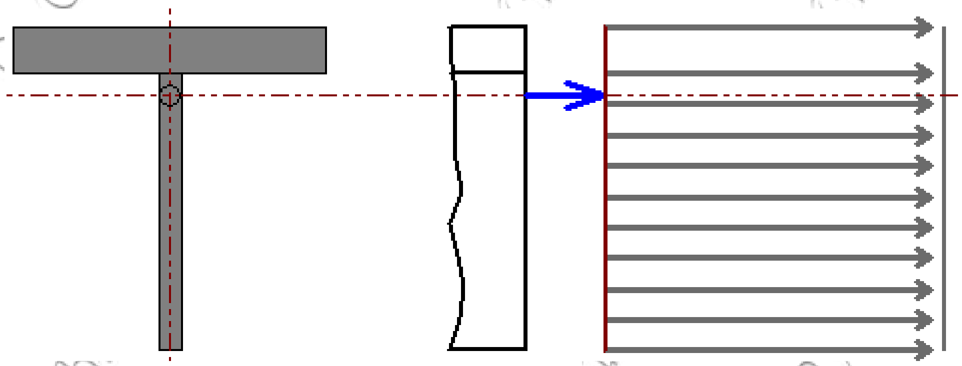


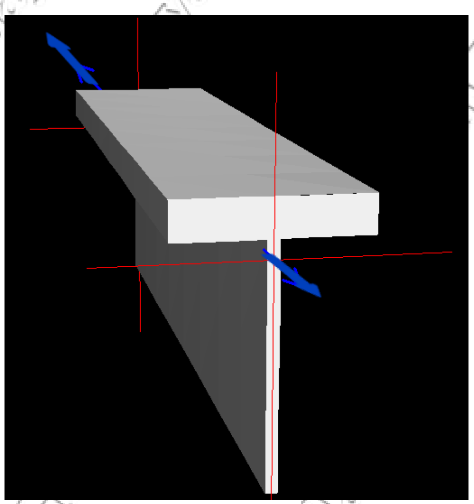
Showing shear deformation

STEEL STRUCTURES

STRUCTURAL ELEMENTS

2. *Ties*: members carrying axial loads in **tension**.

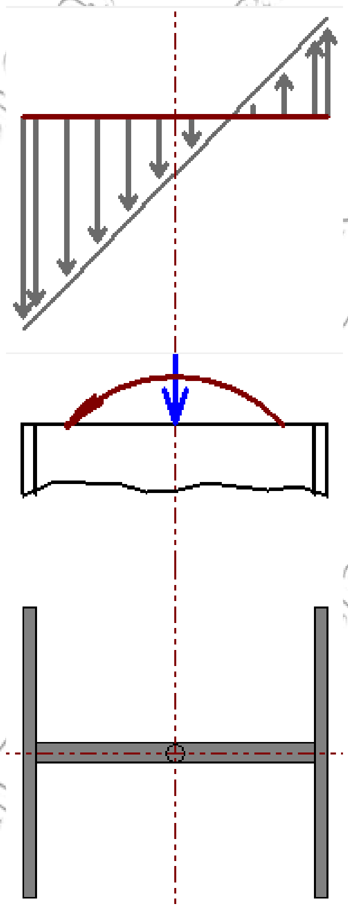


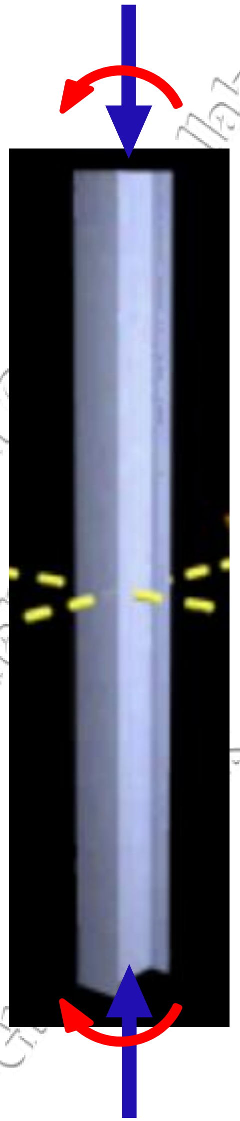


STEEL STRUCTURES

STRUCTURAL ELEMENTS

3. *Struts, columns or stanchions*: members carrying axial loads in compression. These members are often subjected to **bending** as well as **compression**.





STEEL STRUCTURES

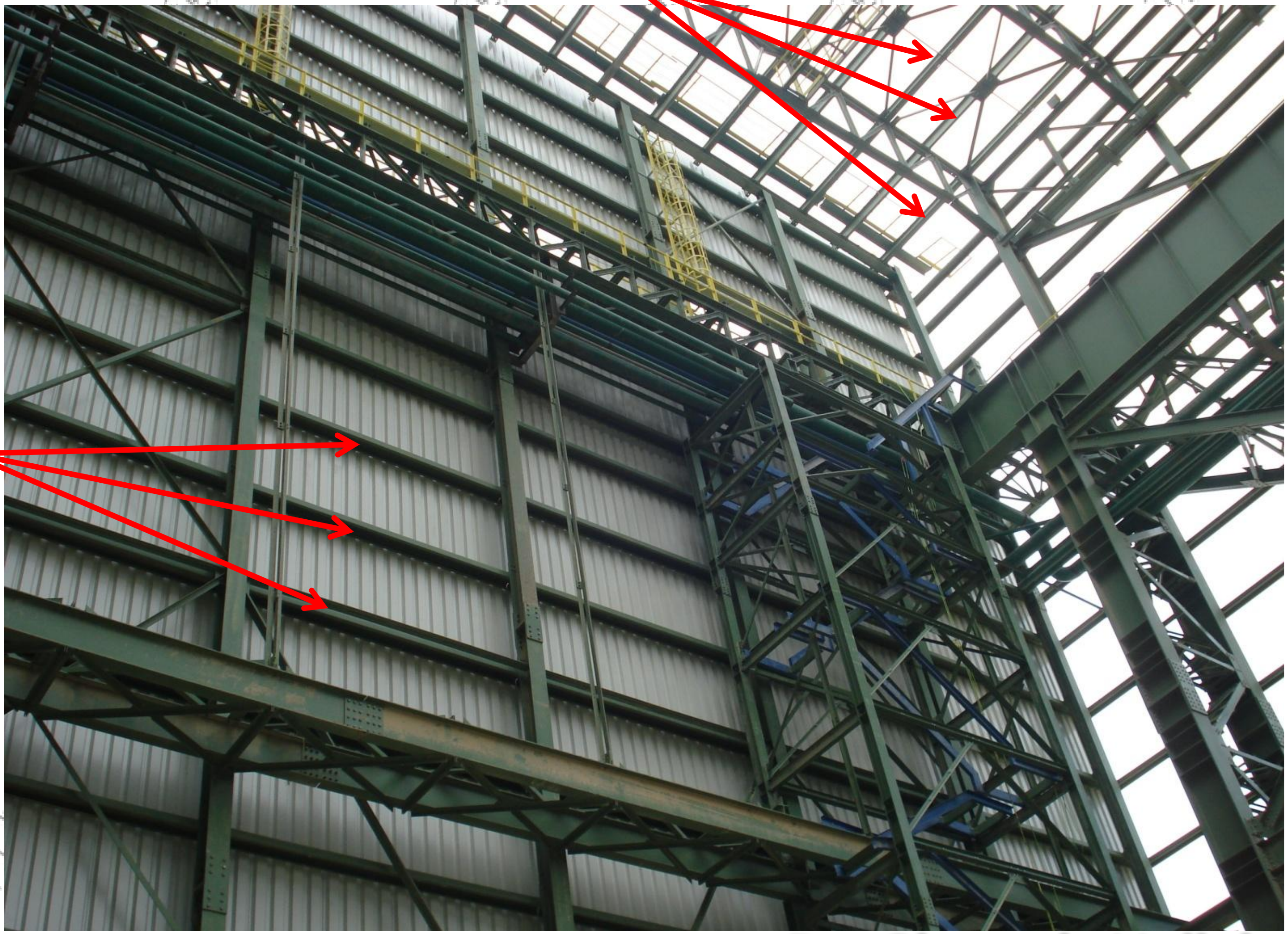
STRUCTURAL ELEMENTS

4. *Trusses and lattice girders*: framed members carrying lateral loads. These are composed of struts and ties.

STEEL STRUCTURES

STRUCTURAL ELEMENTS

5. *Purlins*: beam members carrying roof sheeting.



6. *Sheeting rails*: beam members supporting wall cladding.

STEEL STRUCTURES

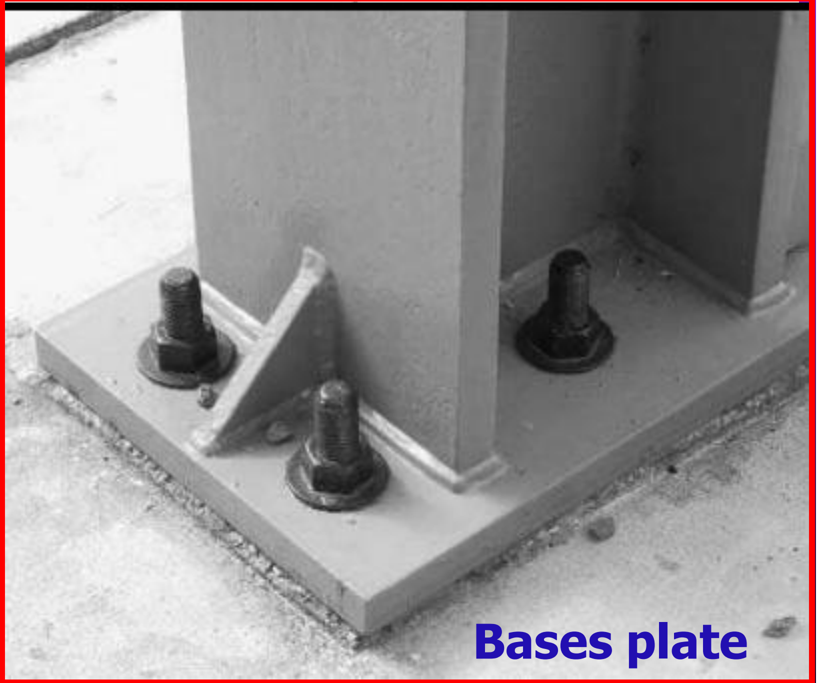
STRUCTURAL ELEMENTS

7. *Bracing*: diagonal struts and ties that, with columns and roof trusses, form vertical and horizontal trusses to resist wind loads and hence provided the stability of the building.

STEEL STRUCTURES

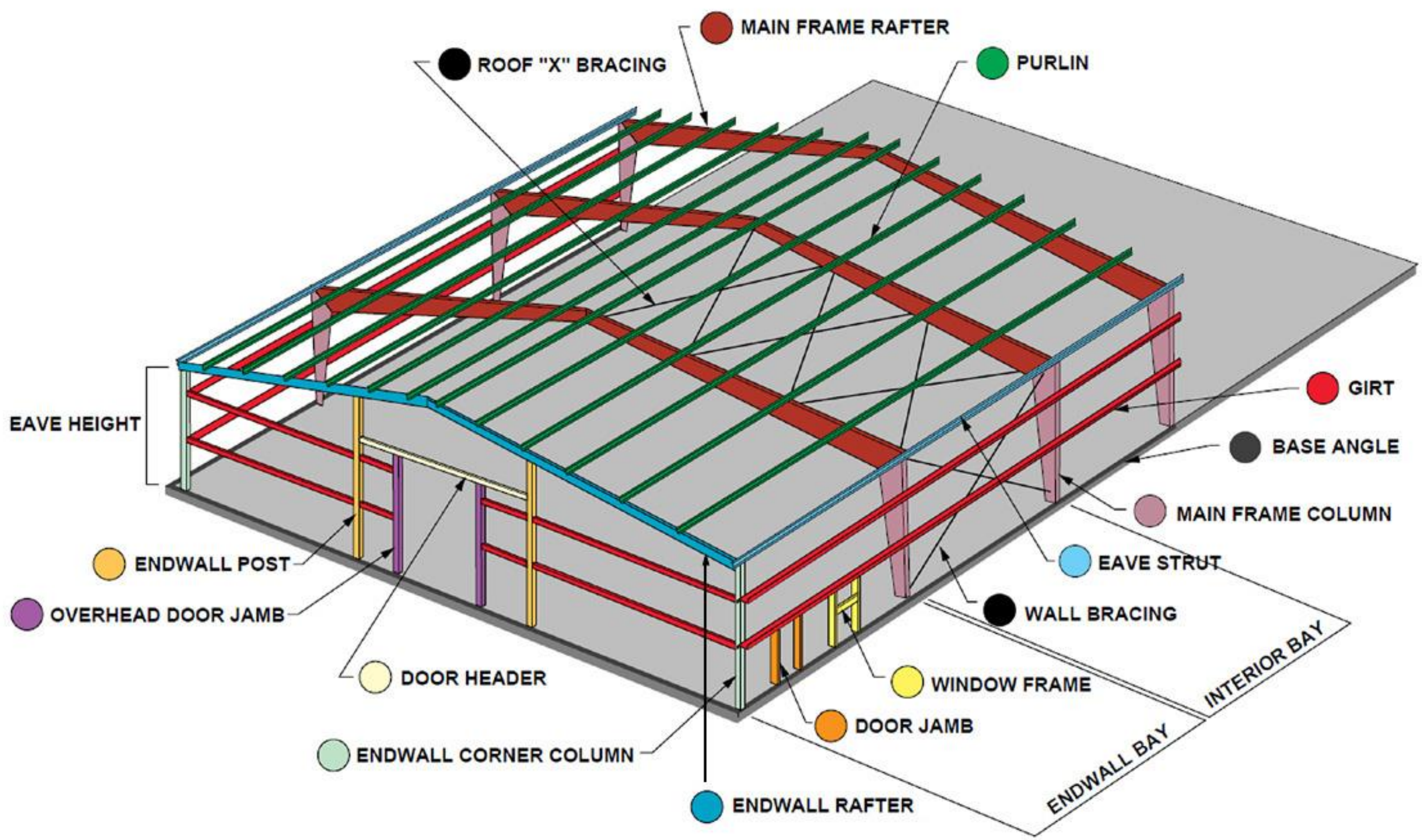
STRUCTURAL ELEMENTS

Joints connect members together such as the joints in trusses, joints between floor beams and columns or other floor beams. Bases transmit the loads from the columns to the foundations.



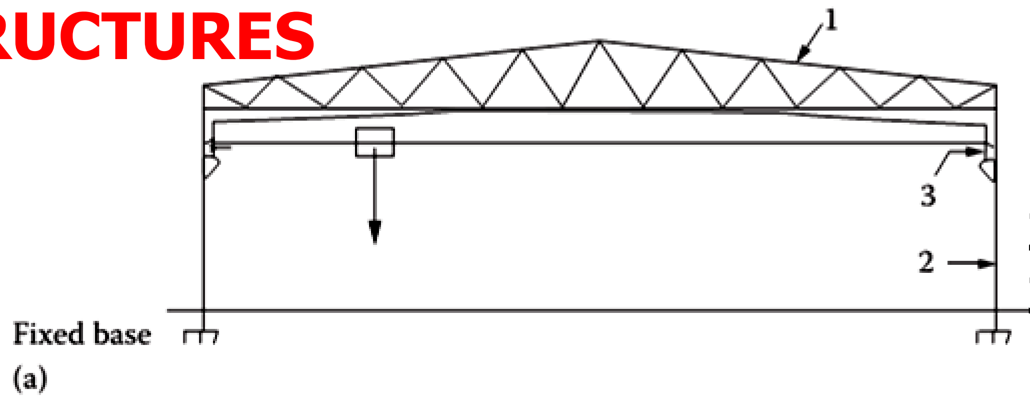
Bases plate

STEEL STRUCTURES
STRUCTURAL ELEMENTS

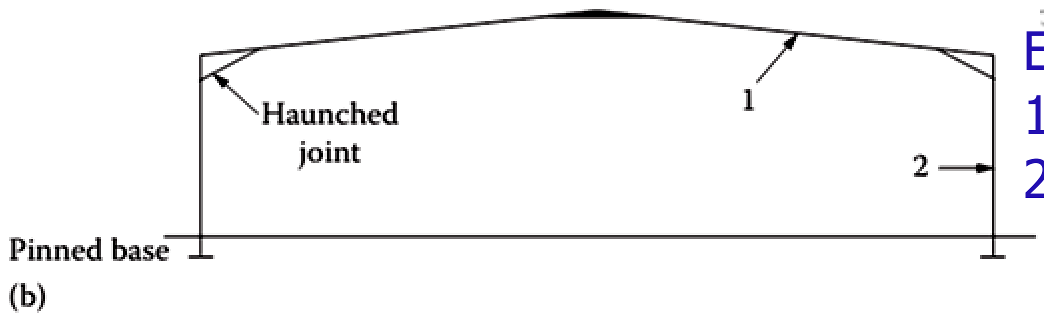


STEEL STRUCTURES

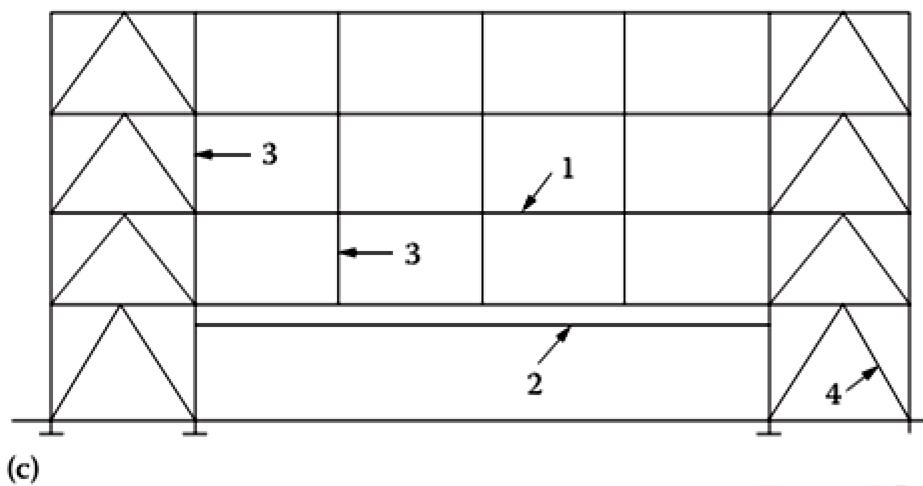
STRUCTURAL ELEMENTS



Elements
1. Lattice girder
2. Crane column
3. Crane girder



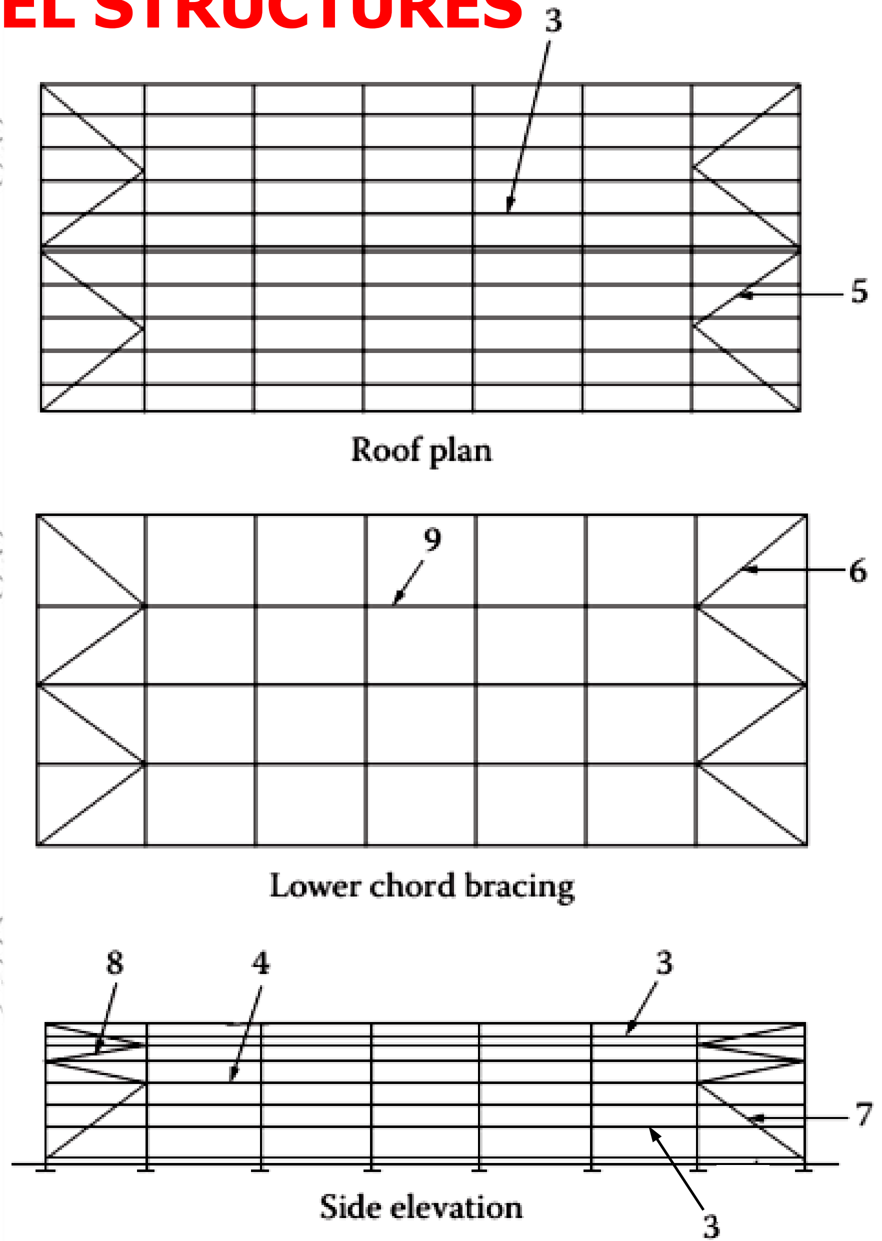
Elements
1. Portal rafter
2. Portal column



Elements
1. Floor beam
2. Plate girder
3. Column
4. Bracing

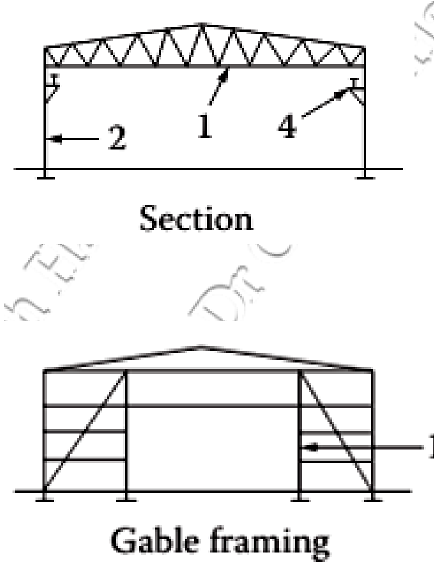
STEEL STRUCTURES

STRUCTURAL ELEMENTS



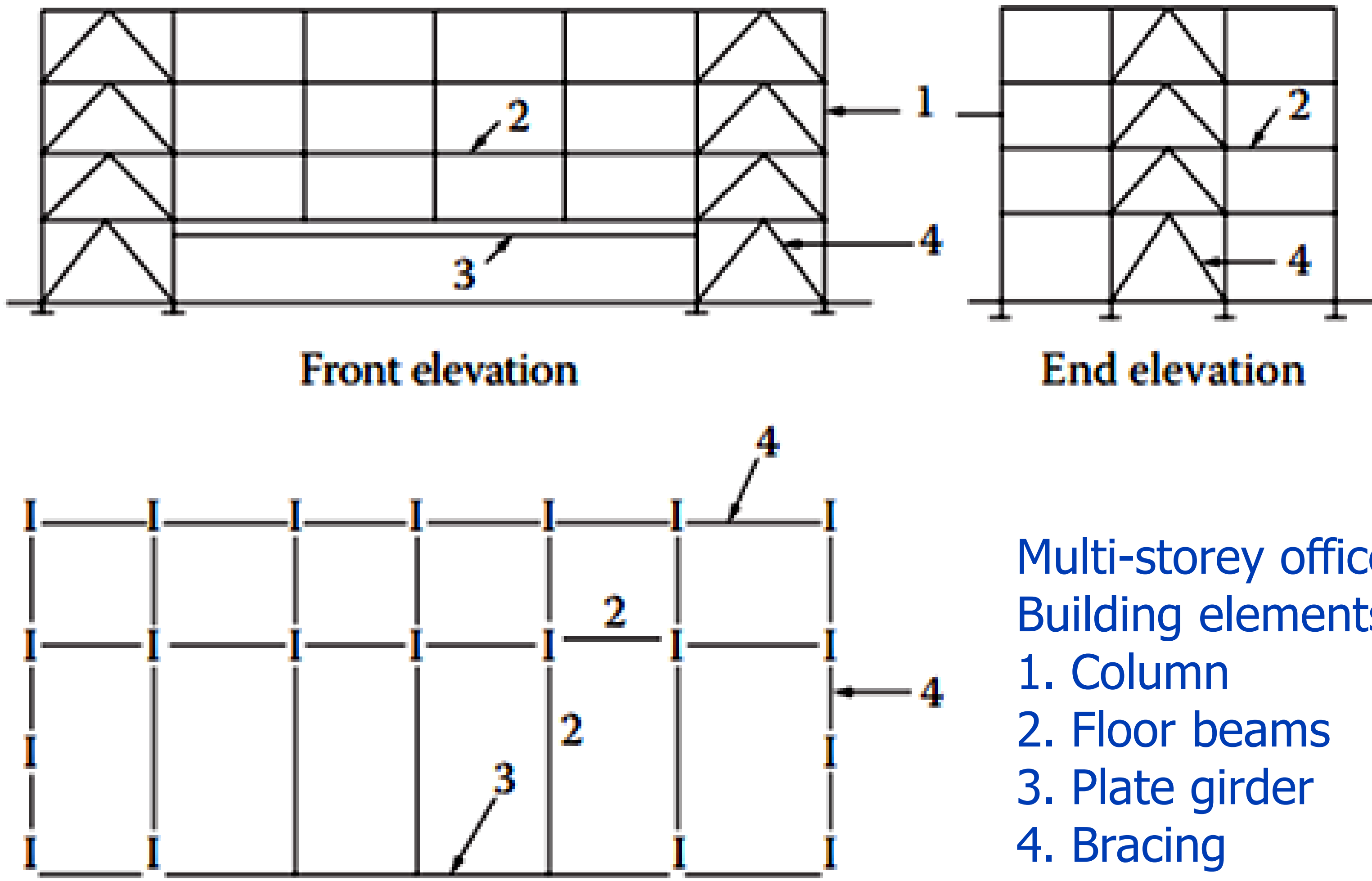
Factory Building elements

1. Lattice girder
2. Column
3. Purlins and sheeting rails
4. Crane girder
6. Lower chord bracing
7. Wall bracing
8. Eaves tie
9. Ties
5. Roof bracing
10. Gable column



STEEL STRUCTURES

STRUCTURAL ELEMENTS



Front elevation

End elevation

Plan first floor level

Multi-storey office Building elements

1. Column
2. Floor beams
3. Plate girder
4. Bracing

STEEL STRUCTURES

STRUCTURAL DESIGN

For a given framing arrangement, the problem in structural design consists of:

1. Estimation of loading
2. Analysis of main frames, trusses or lattice girders, floor systems, bracing and connections to determine axial loads, shears and moments at critical points in all members
3. Design of the elements and connections using design data from step 2.
4. Production of arrangement and detail drawings from the designer's sketches.

STEEL STRUCTURES
DESIGN METHODS

Steel design may be based on three design theories:

1. Elastic design (*Working stress design*)
2. Plastic design (*Ultimate load design)*
3. Limit-state design

1-Elastic design (*Working stress design*) is the traditional method and is still commonly used in the United States. Steel is almost perfectly elastic up to the yield point, and elastic theory is a very good method on which the method is based. Structures are analysed by elastic theory, and sections are sized so that the *permissible stresses* are not exceeded.

$$Working \ \ stress \le permissible \ \ stress \approx \frac{(yielding \ \ or \ ultimate)\, stress}{\gamma_e}$$

$$\gamma_e \approx 1.7 \quad Elastic \ \ Safty \ \ Factore$$

STEEL STRUCTURES

DESIGN METHODS

The working stress methods of design required that the stresses calculated from the most adverse combination of loads must not exceed the specified permissible stresses.

2- Plastic theory (*Ultimate load)* developed to take account of behaviour past the yield point is based on finding the load that causes the structure to collapse. Then the working load is the collapse load divided by a load factor γ_p. The ultimate load methods of designing steel structures required that the calculated ultimate load-carrying capacity of the complete structure must not exceed the most adverse combination of the loads obtained by multiplying the working loads by the appropriate load factors γ_p. Thus

$$\Sigma(\text{Working load} \times \gamma_p) \leq \text{Ultimate load}$$

$$\gamma_p \approx 1.7 \quad \textit{Load Factor}$$

STEEL STRUCTURES

DESIGN METHODS

2- Plastic theory (*Ultimate load)*

This approach is based on **plastic analysis** in which the loads required to cause the structure to collapse are calculated (Ultimate loads). The reasoning behind this method is that, in most steel structures, particularly redundant ones, the loads required to cause the structure to collapse are somewhat larger than the ones which cause yielding. Design, based on this method, calculates the loading required to cause complete collapse and then ensures that this load (Ultimate loads) is greater than the applied loading (working loads); the ratio of collapse load to the maximum applied load (working loads) is called the ***load factor*** γ_p.

$$\textbf{Ultimate load / Working load} = \gamma_p$$

STEEL STRUCTURES

DESIGN METHODS

3- Limit-state design has been developed to take account of all conditions that can make the structure become unfit for use. The design is based on the actual behaviour of materials and structures in use and is in accordance with EN1993.

A structure should not during its lifetime become 'unserviceable', that is, it should be free from risk of collapse, rapid deterioration, fire, cracking, excessive deflection, etc.

Thus for limit states design, the structure is deemed to be satisfactory if

Design load effect ≤ Design resistance

$$\Sigma\ \gamma_f \times \text{(effect of specified loads)} \leq \text{(specified resistance}/\gamma_M\text{)}$$

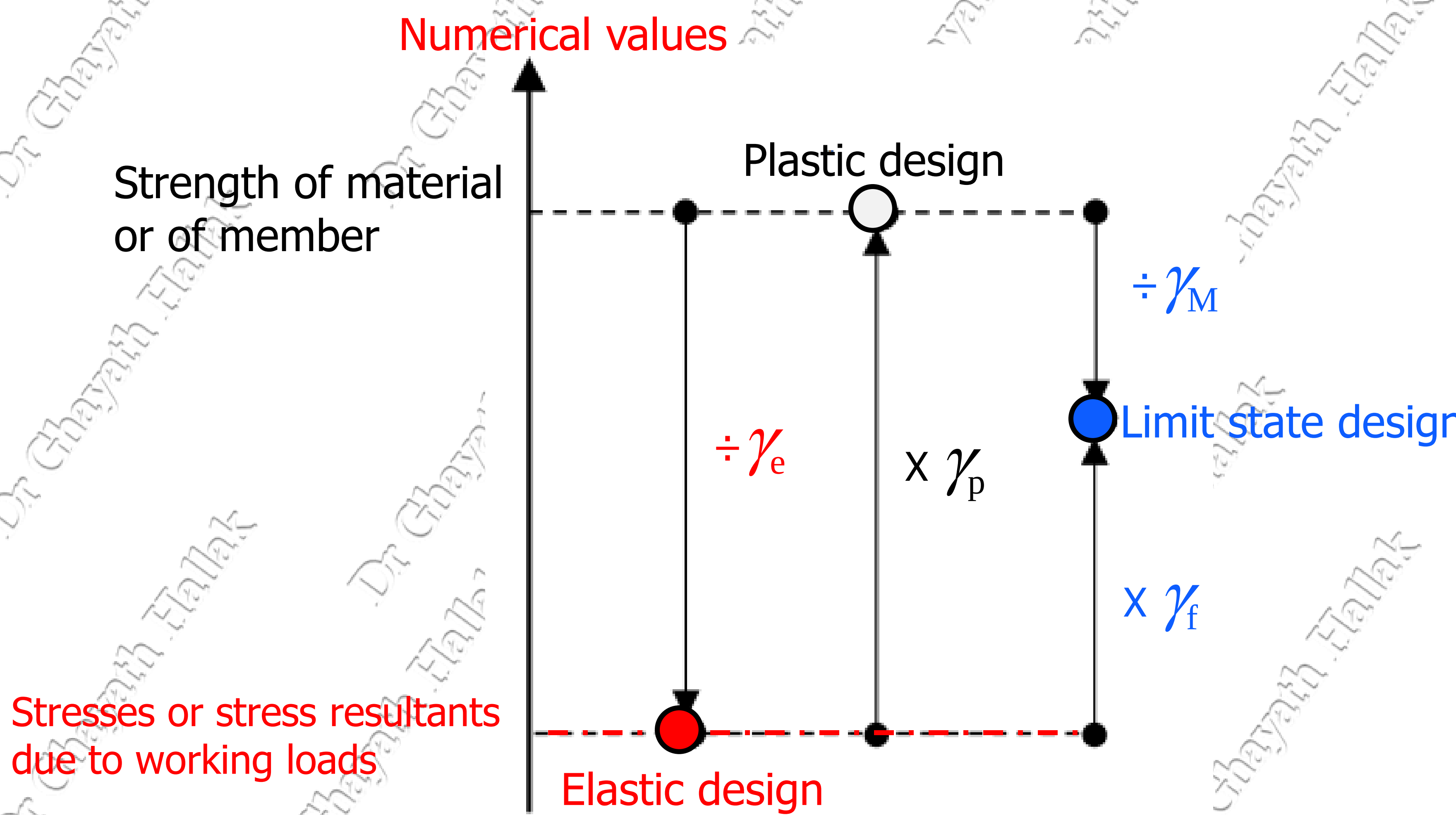
partial load factors γ_G , γ_Q

internal forces (axial, shear, bending moment)

$E_d \leq R_d$

material partial factors

STEEL STRUCTURES DESIGN METHODS



Eurocode program

EN 1990: Basis of structural design

EN 1991-1 Eurocode 1: Actions on structures

Part 1: General actions

- Part 1-1: Densities, self weight and imposed loads for buildings
- Part 1-3: Snow loads
- Part 1-4: Wind actions
- Part 1-5: Thermal actions
- Part 1-6: Actions during Execution
- Part 1-7: Accidental actions from impact and explosions

Part 2: General actions

Traffic loads on Bridges

Eurocode 2
EN 1992 – Design of concrete structures

Eurocode 3
EN 1993: Design of steel structures

Eurocode 4
EN 1994: Design of composite steel and concrete structures

Eurocode 5
EN 1995: Design of timber structures

Eurocode 6
EN 1996: Design of masonry structures

Eurocode 7
EN 1997: Geotechnical design

Eurocode 8
EN 1998: Design of structures for earthquake resistance

Eurocode 9
EN 1999: Design of aluminium structures

EN 1993 is broken into 6 parts. Part 1 has 12 sub-parts:

EN 1993-1-1	Eurocode 3: Design of Steel Structures - Part 1-1: General rules and rules for buildings
EN 1993-1-2	Eurocode 3: Design of Steel Structures - Part 1-2: General rules – structural fire design
EN 1993-1-3	Eurocode 3: Design of Steel Structures - Part 1-3: General rules – cold formed thin gauge members and sheeting
EN 1993-1-4	Eurocode 3: Design of Steel Structures - Part 1-4: General rules – structures in stainless steel
EN 1993-1-5	Eurocode 3: Design of Steel Structures - Part 1-5: General rules – strength and stability of planar plated structures without transverse loading
EN 1993-1-6	Eurocode 3: Design of Steel Structures - Part 1-6: General rules – strength and stability of shell structures
EN 1993-1-7	Eurocode 3: Design of Steel Structures - Part 1-7: General rules – design values for plated structures subjected to out of plane loading
EN 1993-1-8	Eurocode 3: Design of Steel Structures - Part 1-8: General rules - design of joints

EN 1993 is broken into 6 parts. Part 1 has 12 sub-parts:

EN 1993-1-9	Eurocode 3: Design of Steel Structures - Part 1-9: General rules – fatigue strength
EN 1993-1-10	Eurocode 3: Design of Steel Structures - Part 1-10: General rules – material toughness and through thickness assessment
EN 1993-1-11	Eurocode 3: Design of Steel Structures - Part 1-11: General rules – design of structures with tension components
EN 1993-1-12	Eurocode 3: Design of Steel Structures - Part 1-12: General rules -supplementary rules for high strength steels
EN 1993-2	Eurocode 3: Design of Steel Structures - Part 2: Bridges
EN 1993-3-1	Eurocode 3: Design of Steel Structures - Part 3-1: Towers, masts and chimneys -towers and masts
EN 1993-3-2	Eurocode 3: Design of Steel Structures - Part 3-2: Towers, masts and chimneys - chimneys
EN 1993-4-1	Eurocode 3: Design of Steel Structures - Part 4-1: Silos, tanks and pipelines - silos

EN 1993 is broken into 6 parts. Part 1 has 12 sub-parts:

EN 1993-4-1	Eurocode 3: Design of Steel Structures - Part 4-1: Silos, tanks and pipelines - silos
EN 1993-4-2	Eurocode 3: Design of Steel Structures - Part 4-2: Silos, tanks and pipelines -tanks
EN 1993-4-3	Eurocode 3: Design of Steel Structures - Part 4-3: Silos, tanks and pipelines -pipelines
EN 1993-5	Eurocode 3: Design of Steel Structures - Part 5: Piling
EN 1993-6	Eurocode 3: Design of Steel Structures - Part 6: Crane supporting structures

BS EN 1993: Design of steel structures
Part 1-1: General rules and rules for buildings

Chapter 1	General
Chapter 2	Basis of Design
Chapter 3	Materials
Chapter 4	Durability
Chapter 5	Structural analysis
Chapter 6	Ultimate limit states
Chapter 7	Serviceability limit states
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

LIMIT-STATE DESIGN PRINCIPLES

1- All separate conditions that make the structure unfit for use {either causing collapse (Yeilding- Buckling...) or Not (Excessive Deflection Vibration....)} are taken into account.

2. The design is based on the actual behaviour of materials and performance of structures and members in service.(the strengths are calculated using plastic theory, and post-buckling behaviour is taken into account. The effect of imperfections on design strength is also included.)

3- Ideally, design should be based on statistical methods with a small probability of the structure reaching a limit state. Partial factors of safety are introduced to take account of all the uncertainties in loads, materials strengths, approximations are used in design and imperfections in fabrication and erection

DESIGN METHODS
LIMIT STATES FOR STEEL DESIGN

Ultimate limit states	Serviceability limit states
1. Strength (including general yielding, rupture, buckling and transformation into a mechanism)	5. Deflection
2. Stability against overturning and sway	6. Vibration (e.g. wind-induced oscillation)
3. Fracture due to fatigue	7. Repairable damage due to fatigue
4. Brittle fracture	8. Corrosion and durability
When the ultimate limit states are exceeded, the whole structure or part of it collapses.	when exceeded, make the structure or part of it unfit for normal use but do not indicate that collapse has occurred.

WORKING AND FACTORED LOADS

Working loads

The working loads (specified, characteristic or nominal loads) are the actual loads the structure is designed to carry. These are normally thought of as the maximum loads that will not be exceeded during the life of the structure. In statistical terms, characteristic loads have a 95% probability of not being exceeded.

Factored loads for the ultimate limit states

In accordance with EN1990, factored loads are used in design calculations for strength and equilibrium.

Factored load = working or nominal load × relevant partial load factor, γ_f

SERVICEABILITY LIMIT-STATE DEFLECTION

Deflection of beams due to unfactored imposed loads	
Cantilevers	Length/180
Beams carrying plaster or other brittle finish	Span/360`
All other beams (except purlins and sheeting rails)	Span/200
Purlins and sheeting rails	To suit the characteristics of particular cladding
Horizontal deflection of columns due to unfactored imposed and wind loads	
Tops of columns in single-storey buildings except portal frames	Height/300
In each storey of a building with more than one storey	Storey height/300

Mechanical Properties of Structural Steel

3.1 STRUCTURAL STEEL PROPERTIES

The steel used in structural engineering is a compound of approximately 98% iron and small percentages of carbon, silicon, manganese, phosphorus, sulphur, niobium and vanadium. Copper and chromium are added to produce the weather-resistant steels that do not require corrosion protection.

Increasing the carbon content increases strength and hardness but reduces ductility and toughness. Carbon content therefore is restricted to between 0,25% and 0,2% to produce a steel that is weldable and not brittle. The niobium and vanadium are introduced to raise the yield strength of the steel; the manganese improves corrosion resistance; and the phosphorus and sulphur are impurities.

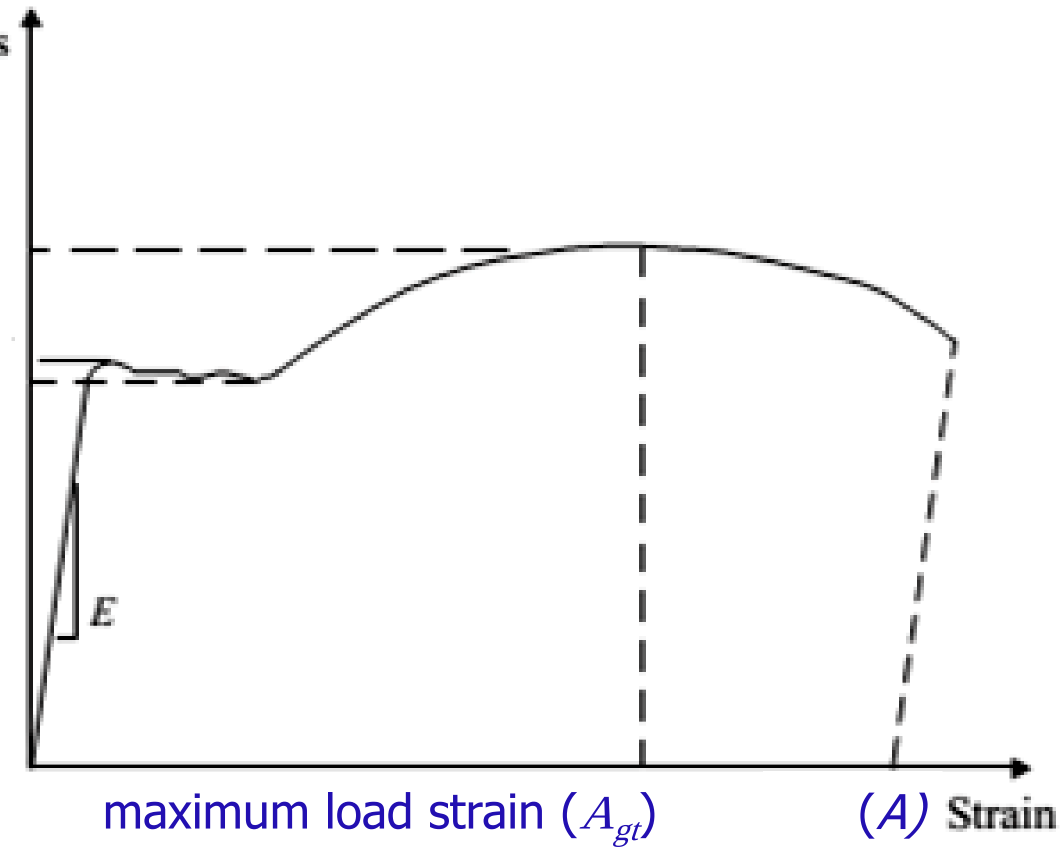
Mechanical Properties of Structural Steel

STRUCTURAL STEEL PROPERTIES

Tensile strength $f_u = R_m$

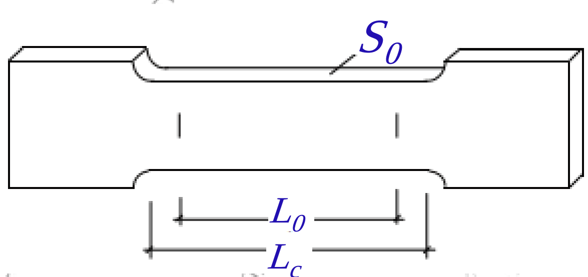
upper yield stress $f_y = R_{eH}$

lower yield stress R_{eL}



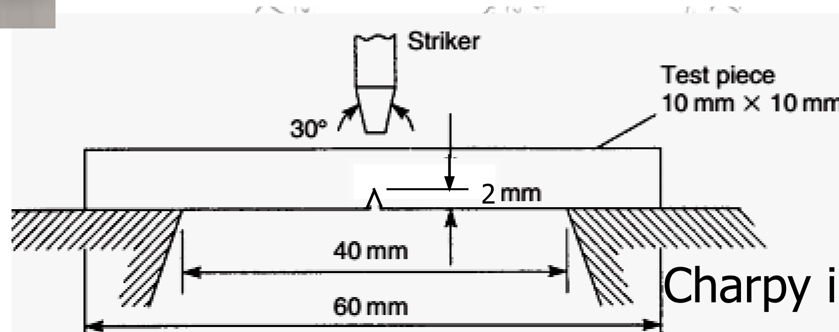
maximum load strain (A_{gt})

(A) strain after failure



$$L_0 = 5.65\sqrt{S_0}$$

$$L_c \geq \left(L_0 + 1.5\sqrt{S_0}\right)$$



Charpy impact test

Mechanical Properties of Structural Steel

STRUCTURAL STEEL PROPERTIES

- S Structural steel.
- E Engineering steel.
- 235 Minimum yield strength (R_{eH}) in MPa at 16mm
- JR Longitudinal Charpy V-notch impacts 27 J at + 20°C
- J0 Longitudinal Charpy V-notch impacts 27 J at 0°C
- J2 Longitudinal Charpy V-notch impacts 27 J at - 20°C
- K2 Longitudinal Charpy V-notch impacts 40 J at - 20°C

Hot-rolled steel grades and qualities according to EN 10025-2

Steel grades and qualities	Minimum yield strength R_{eH} (MPa)				Tensile strength R_m (MPa)		Minimum percentage elongation after fracture $L_o = 5.65\sqrt{S_o}$		
	Nominal thickness (mm)				Nominal thickness (mm)		Nominal thickness (mm)		
	≤ 16	>16 ≤ 40	>40 ≤ 63	>63 ≤ 80	< 3	≥3 ≤ 100	≥3 ≤ 40	>40 ≤ 63	>63 ≤ 100
S 235JR	235	225	215	215	360 to 510	360 to 510	26	25	24
S 235J0	235	225	215	215	360 to 510	360 to 510			
S 235J2	235	225	215	215	360 to 510	360 to 510	24	23	22
S 275JR	275	265	255	245	430 to 580	410 to 560	23	22	21
S 275J0	275	265	255	245	430 to 580	410 to 560			
S 275J2	275	265	255	245	430 to 580	410 to 560	21	20	19
S 355JR	355	345	335	325	510 to 680	470 to 630	22	21	20
S 355J0	355	345	335	325	510 to 680	470 to 630			
S 355J2	355	345	335	325	510 to 680	470 to 630			
S 355K2	335	345	335	325	510 to 680	470 to 630	20	19	18
S 450J0	450	430	410	390	-	550 to 720	17	17	17

STRUCTURAL STEEL PROPERTIES

Elastic properties of steel as material

- ❑- Modulus of elasticity E = 210 GPa;
- ❑- The elastic shear modulus G=81000Mpa, $G=E/[2(1+\nu)]$
- ❑- Poisson's ratio in elastic range $\nu = 0.3$;
- ❑- Coefficient of linear thermal expansion α = 12x10-6 /ºC;
- ❑- Volumetric mass ρ = 7850 kg/m3.

Ductility requirements

Ductility is the ability of a material to undergo large deformation without breaking.

NA to BS EN 1993-1-1 sets the following requirements:

1. Elastic global analysis
   a. $f_u/f_y \geq 1.10$
   b. Elongation at failure not less than 15% (on a gauge length of $5.65\sqrt{S_0}$, where S_0 is the original cross-sectional area)

STRUCTURAL STEEL PROPERTIES

Ductility requirements

c. $\varepsilon_u \geq 15\, \varepsilon_y$ where ε_u is the ultimate strain and ε_y is the yield strain

2. Plastic global analysis

Plastic global analysis should not be used for bridges.

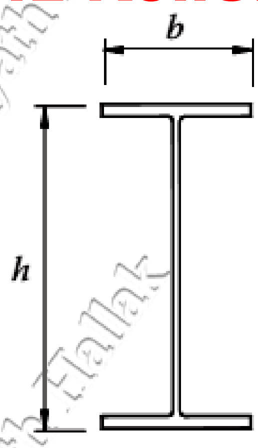
a. $f_u/f_y \geq 1.15$

b. Elongation at failure not less than 15% (on a gauge length of $5.65\sqrt{S_0}$, where S_0 is the original cross-sectional area)

c. $\varepsilon_u \geq 20\, \varepsilon_y$, where ε_u is the ultimate strain and ε_y is the yield strain

3.3 STEEL SECTIONS

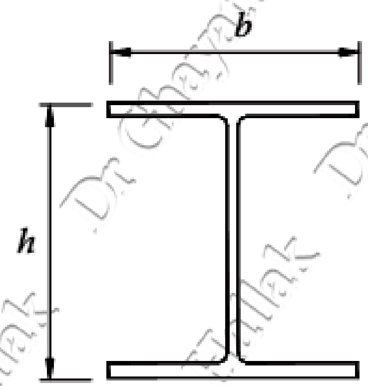
3.3.1 Rolled and formed sections



$h \times b$ 127 ×76–1016 × 305

Universal beam

resisting bending moment about the major axis

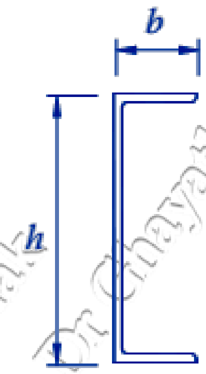


$h \times b$ 152 × 152–356 × 406

Universal column

resist axial load

$i_y \approx i_z$

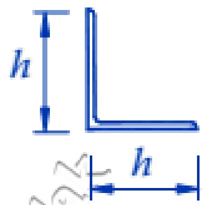


$h \times b$ 100 ×50–430 × 100

Parallel angel channel

used for beams, bracing members, truss members , compound members.

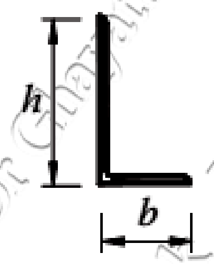
3.3 STEEL SECTIONS
3.3.1 Rolled and formed sections



$h \times h$ 20 × 20–200 × 200

Equal angle

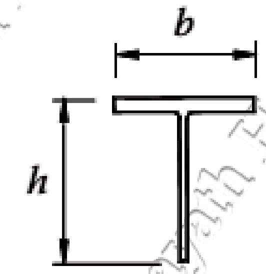
used for bracing members, truss members and for purlins, side and sheeting rails.



$h \times b$ 30 × 20–200 × 150

Unequal angle

used for bracing members, truss members and for purlins, side and sheeting rails.



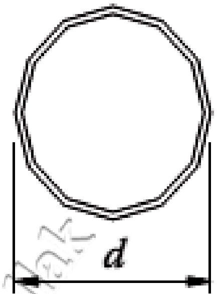
$h \times b$ 133 ×102–305 × 457

Structural tee cut form UB

used for truss members, ties and light beams.

3.3 STEEL SECTIONS

3.3.1 Rolled and formed sections

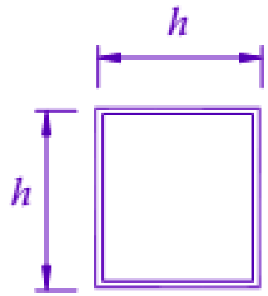


26.9 to 193.7 Hot-finished

33.7 to 508.0 Cold-formed

Circular Hollow Section

compression members

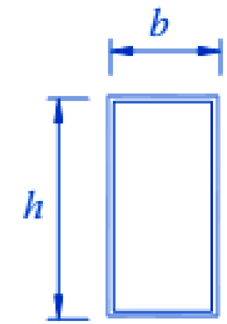


h × *h* 40 × 40–400 × 400 Hot-finished

h × *h* 25 × 25–400 × 400 Cold-formed

Square Hollow Section

compression members



h × *b* 50 × 30–500×300 Hot-finished

h × *b* 50×25–500×300Cold-formed

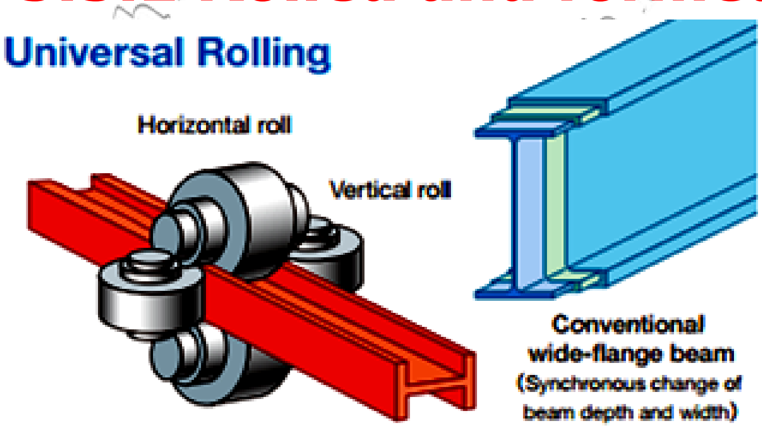
Rectangular Hollow Section

compression members

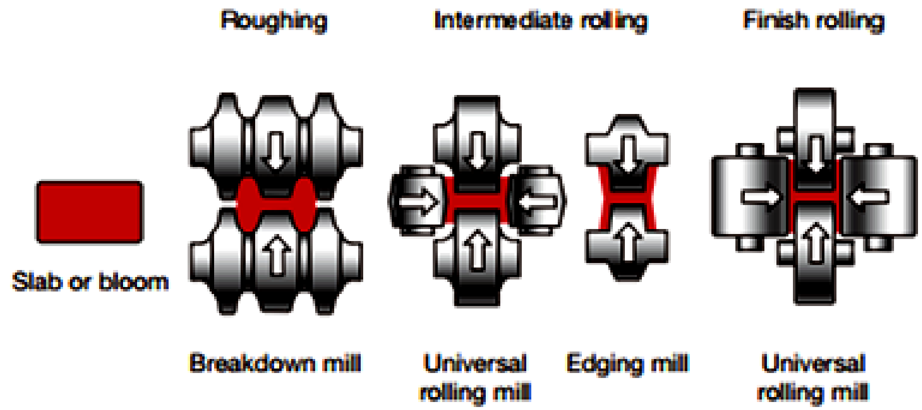
Used in roof trusses, lattice girders, building frames and for purlins, sheeting rails, etc.

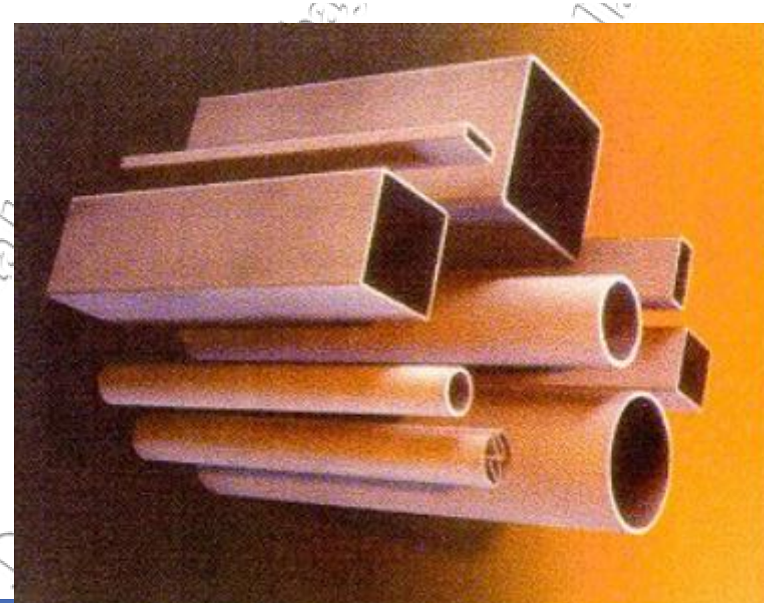
3.3 STEEL SECTIONS
3.3.1 Rolled and formed sections

Universal Rolling



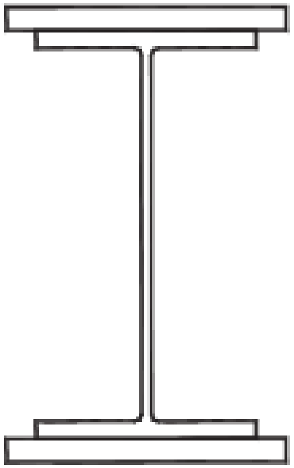
Universal roll for rolling wide-flange beam

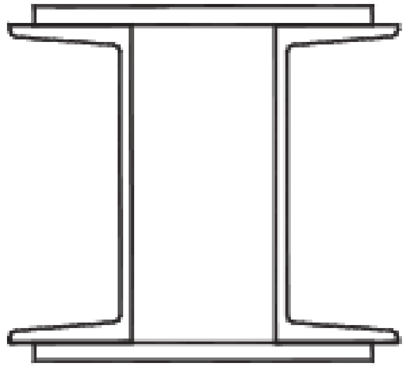


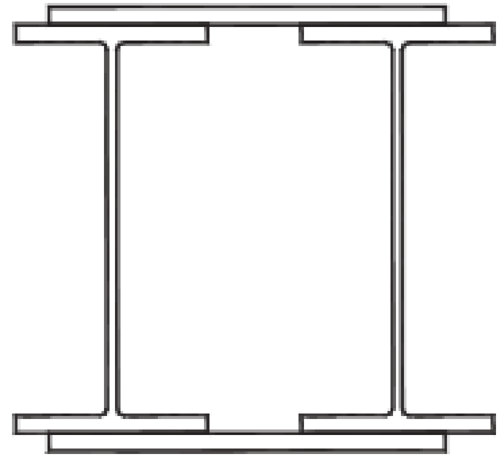


3.3 STEEL SECTIONS

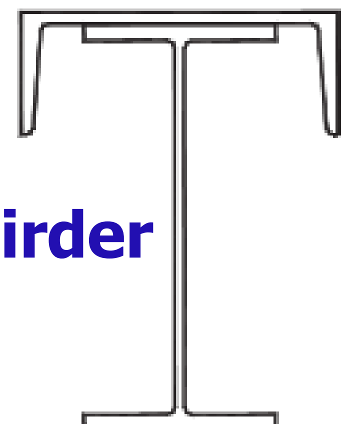
3.3.2 Compound sections



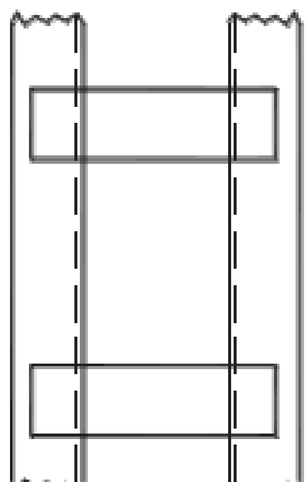




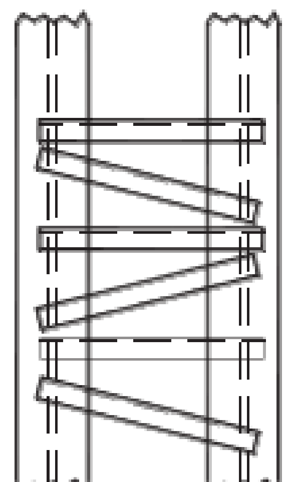
compound beam



crane girder



battened member



laced member

3.3 STEEL SECTIONS

3.3.3 Built-up sections

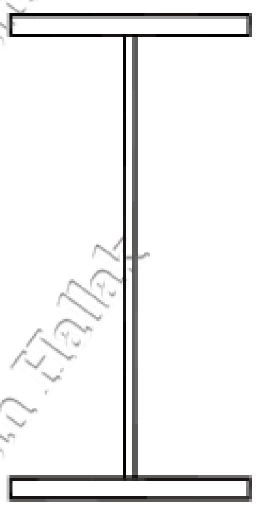
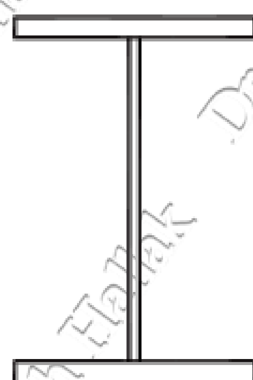
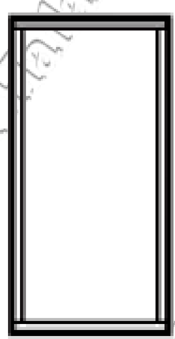


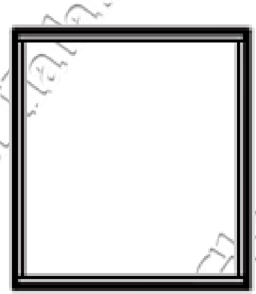
Plate girder



Built-up section



Box girder



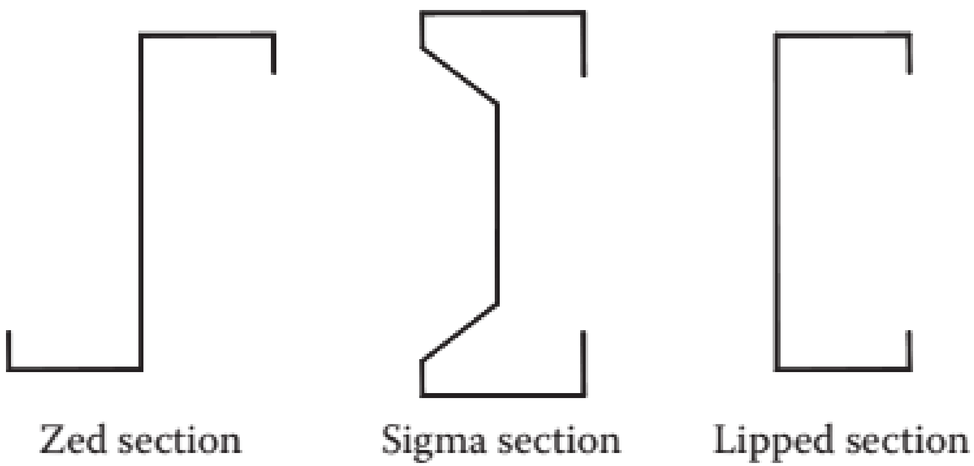
Box column

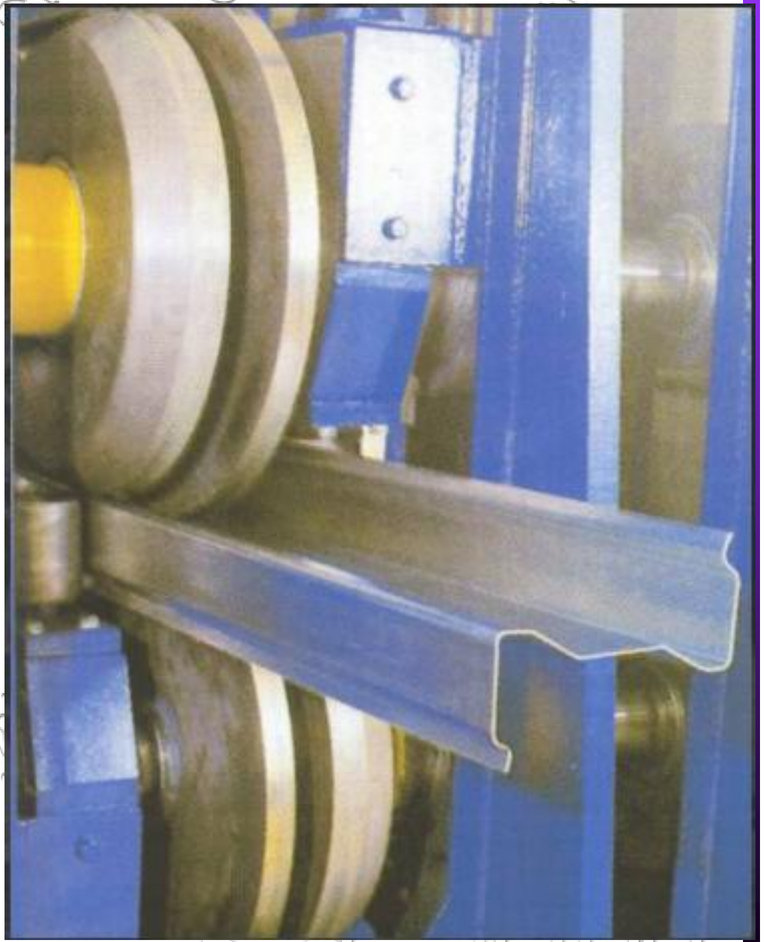
3.3 STEEL SECTIONS

3.3.4 Cold-rolled open sections

Thin steel plates can be formed into a wide range of sections by cold rolling.

Used for purlins, side and sheeting rails





3.3 STEEL SECTIONS
3.4 SECTION PROPERTIES

BS EN 1993-1-1: 2005
BS 4-1: 2005

UK EUROCODES

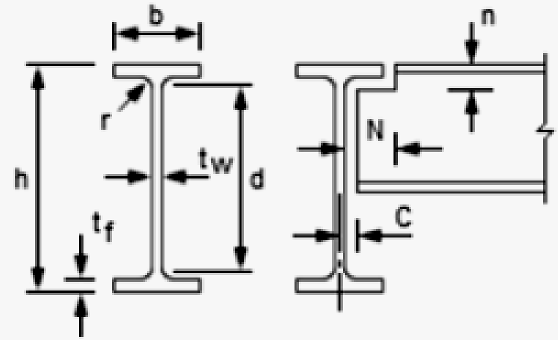
B-2

SECTION PROPERTIES

UNIVERSAL BEAMS

Advance® UKB

DIMENSIONS



Section Designation	Mass per Metre	Depth of Section	Width of Section	Thickness		Root Radius	Depth between Fillets	Ratios for Local Buckling		Dimensions for Detailing			Surface Area	
				Web	Flange			Flange	Web	End Clearance	Notch		Per Metre	Per Tonne
		h	b	t_w	t_f	r	d	c_f / t_f	c_w / t_w	C	N	n		
	kg/m	mm	mm	mm	mm	mm	mm			mm	mm	mm	m^2	m^2
1016 x 305 x 487 +	486.7	1036.3	308.5	30.0	54.1	30.0	868.1	2.02	28.9	17	150	86	3.20	6.58
1016 x 305 x 437 +	437.0	1026.1	305.4	26.9	49.0	30.0	868.1	2.23	32.3	15	150	80	3.17	7.25
1016 x 305 x 393 +	392.7	1015.9	303.0	24.4	43.9	30.0	868.1	2.49	35.6	14	150	74	3.14	8.00
1016 x 305 x 349 +	349.4	1008.1	302.0	21.1	40.0	30.0	868.1	2.76	41.1	13	152	70	3.13	8.96
1016 x 305 x 314 +	314.3	999.9	300.0	19.1	35.9	30.0	868.1	3.08	45.5	12	152	66	3.11	9.89
1016 x 305 x 272 +	272.3	990.1	[illegible]	16.5	31.0	30.0	868.1	3.60	[illegible]	10	152	62	3.10	11.4
1016 x 305 x 249 +		980.1		16.5	26.0		868.1	[illegible]		10	[illegible]	56	3.08	[illegible]
[illegible]														

3.3 STEEL SECTIONS
3.4 SECTION PROPERTIES

BS EN 1993-1-1: 2005
BS 4-1: 2005

UK EUROCODES

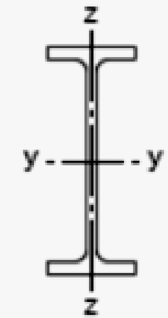
B-3

SECTION PROPERTIES

UNIVERSAL BEAMS

Advance® UKB

PROPERTIES



Section Designation	Second Moment of Area		Radius of Gyration		Elastic Modulus		Plastic Modulus		Buckling Parameter	Torsional Index	Warping Constant	Torsional Constant	Area of Section
	Axis y-y	Axis z-z	Axis y-y	Axis z-z	Axis y-y	Axis z-z	Axis y-y	Axis z-z	U	X	I_w	I_T	A
	cm^4	cm^4	cm	cm	cm^3	cm^3	cm^3	cm^3			dm^6	cm^4	cm^2
1016 x 305 x 487 +	1020000	26700	40.6	6.57	19700	1730	23200	2800	0.867	21.1	64.4	4300	620
1016 x 305 x 437 +	910000	23400	40.4	6.49	17700	1540	20800	2470	0.868	23.1	56.0	3190	557
1016 x 305 x 393 +	808000	20500	40.2	6.40	15900	1350	18500	2170	0.868	25.5	48.4	2330	500
1016 x 305 x 349 +	723000	18500	40.3	6.44	14300	1220	16600	1940	0.872	27.9	43.3	1720	445
1016 x 305 x 314 +	644000	16200	40.1	6.37	12900	1080	14800	1710	0.872	30.7	37.7	1260	400
10[illegible]	554000	1[illegible]	[illegible]	6.35	11200	934	12800	1470	0.872	35.[illegible]	[illegible]2	835	347
[illegible]	[illegible]1000	[illegible]	[illegible]	[illegible]	9820	784	11[illegible]	[illegible]	[illegible]861	3[illegible]	[illegible]	[illegible]	3[illegible]

3.3 STEEL SECTIONS -3.4 SECTION PROPERTIES

Poutrelles I européennes (suite)

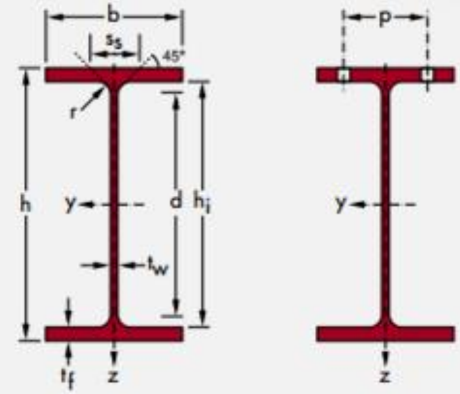
Dimensions: IPE 80 - 600 conformes à l'Euronorme 19-57; IPE A 80 - 600; IPE O 180 - 600; IPE 750
Tolérances: EN 10034: 1993
Etat de surface conforme à EN 10163-3: 1991, classe C, sous-classe 1

European I beams (continued)

Dimensions: IPE 80 - 600 in accordance with Euronorm 19-57; IPE A 80 - 600; IPE O 180 - 600; IPE 750
Tolerances: EN 10034: 1993
Surface condition according to EN 10163-3:1991, class C, subclass 1

Europäische I-Profile (Fortsetzung)

Abmessungen: IPE 80 - 600 gemäß Euronorm 19-57; IPE A 80 - 600; IPE O 180 - 600; IPE 750
Toleranzen: EN 10034: 1993
Oberflächenbeschaffenheit gemäß EN 10163-3: 1991, Klasse C, Untergruppe 1



Désignation / Designation / Bezeichnung		Dimensions / Abmessungen						Dimensions de construction / Dimensions for detailing / Konstruktionsmaße						Surface / Oberfläche	
	G kg/m	h mm	b mm	t_w mm	t_f mm	r mm	A mm^2 x 10^2	h_i mm	d mm	Ø	p_{min} mm	p_{max} mm	A_L m^2/m	A_G m^2/t
IPE A 500*	79,4	497	200	8,4	14,5	21	101	468	426	M 24	100	112	1,741	21,94
IPE 500	90,7	500	200	10,2	16	21	116	468	426	M 24	102	112	1,744	19,23
IPE O 500+	107	506	202	12	19	21	137	468	426	M 24	104	114	1,760	16,40
IPE A 550*	92,1	547	210	[illegible]	15,7	24	117	515,6	467,6	M 24	106	122	1,875	20,36
[illegible]	106	550	[illegible]	[illegible]	[illegible]	24	134	[illegible]	[illegible]	M 24	110	122	[illegible]	17,78
[illegible]	123	556	[illegible]	[illegible]	[illegible]	24	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

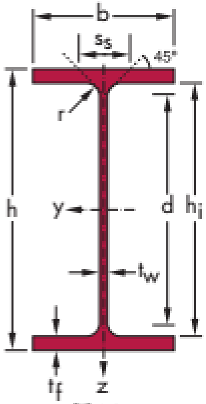
3.3 STEEL SECTIONS
3.4 SECTION PROPERTIES

IPE

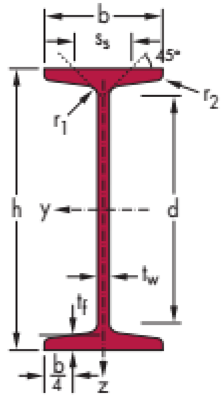
Notations pages 211-215 / Bezeichnungen Seiten 211-215

Désignation / Designation / Bezeichnung	Valeurs statiques / Section properties / Statische Kennwerte: axe fort y-y / strong axis y-y / starke Achse y-y					axe faible z-z / weak axis z-z / schwache Achse z-z							Classification ENV 1993-1-1: pure bending y-y			pure compression			EN 10025:1993	EN 10113-3:1993	EN 10225:2001
	G kg/m	I_y mm⁴	$W_{el.y}$ mm³	$W_{pl.y}$♦ mm³	i_y mm	A_{vz} mm²	I_z mm⁴	$W_{el.z}$ mm³	$W_{pl.z}$♦ mm³	i_z mm	s_s mm	I_t mm⁴	I_w mm⁶	S 235	S 355	S 460	S 235	S 355	S 460			
		x 10⁴	x 10³	x 10³	x 10	x 10²	x 10⁴	x 10³	x 10³	x 10		x 10⁴	x 10⁹									
IPE A 500	79,4	42930	1728	1946	20,61	50,41	1939	193,9	301,6	4,38	62,00	62,78	1125	1	1	-	4	4	-	✔	✔	✔
IPE 500	90,7	48200	1928	2194	20,43	59,87	2142	214,2	335,9	4,31	66,80	89,29	1249	1	1	1	3	4	4	✔	HI	HI
IPE O 500	107	57780	2284	2613	20,56	70,21	2622	259,6	408,5	4,38	74,60	143,5	1548	1	1	1	2	4	4	✔	HI	HI
IPE A 550	92,1	59980	2193	2475	22,61	60,30	2432	231,6	361,5	4,55	68,52	86,53	1710	1	1	-	4	4	-	✔	✔	✔
IPE 550	106	67120	2441	2787	[illegible]	72,34	2668	254,1	400,5	4,45	73,62	123,2	1884	1	1	1	4	4	4	✔	HI	HI
IPE O 55[illegible]	[illegible]	79160	2847	[illegible]	[illegible]	[illegible]	3224	304,2	480,5	[illegible]	[illegible]	187,5	2302	1	1	1	2	4	4	✔	HI	HI
[illegible]	[illegible]	82920	[illegible]	[illegible]	[illegible]	[illegible]	3116	283,3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	3387	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

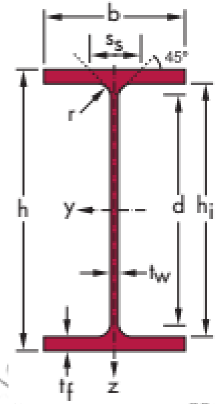
3.3 STEEL SECTIONS
3.4 SECTION PROPERTIES



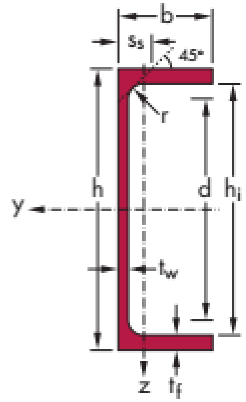
IPE 80-750



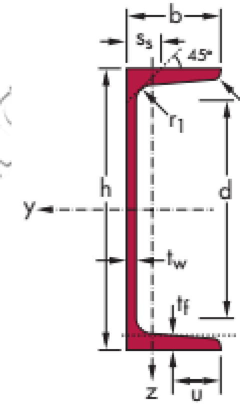
IPN 80-600



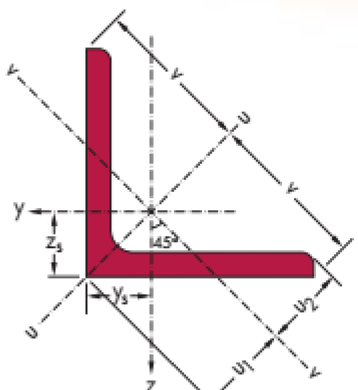
HE 100-1000
HL920-1100



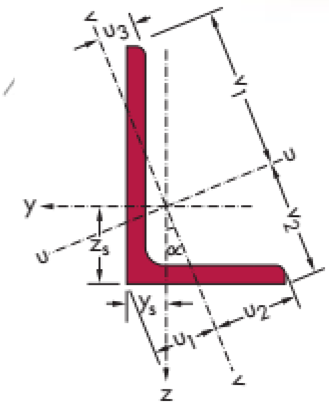
UPE 80-400
UAP80-300



UPN 80-400
U 40x20-65x42



L 20 x 20 x 3
L 250 x 250 x 35



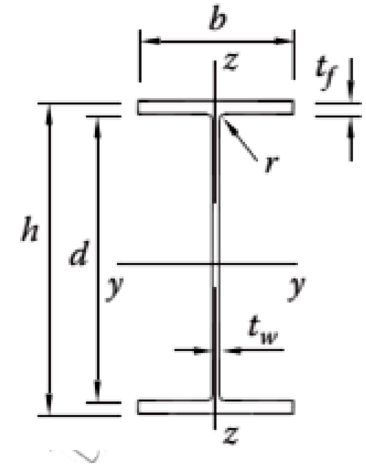
L 120 x 80 x 8
L 200 x 100 x 14

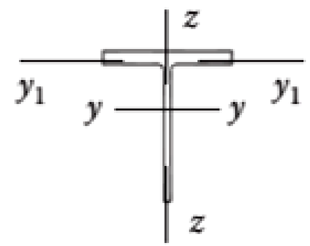
European Sections

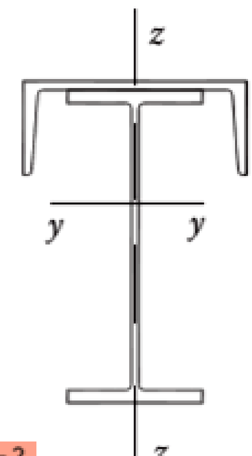
3.3 STEEL SECTIONS
3.4 SECTION PROPERTIES

Elastic Properties

Area	$A = 2bt_f + dt_w$
Moment of inertia y–y axis	$I_y = \frac{bh^3}{12} - \frac{(b - t_w)d^3}{12}$
Moment of inertia z–z axis	$I_z = \frac{2t_f b^3}{12} + \frac{dt_w^3}{12}$
Radius of gyration y–y axis	$i_y = \left(\frac{I_y}{A}\right)^{0.5}$
Radius of gyration z–z axis	$i_z = \left(\frac{I_z}{A}\right)^{0.5}$
Modulus of section y–y axis	$W_{el,y} = \frac{2I_y}{h}$
Modulus of section z–z axis	$W_{el,z} = \frac{2I_z}{b}$







yy Centroidal axis

y_1y_1 Equal area axis

Plastic moduli of section

Equal to the algebraic sum of the first moments of area about the equal area axis

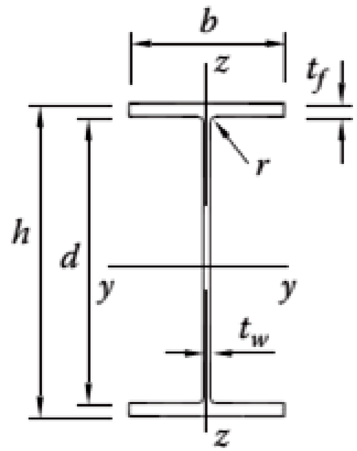
$$W_{pl,y} = \frac{2bt_f(h - t_f)}{2} + \frac{t_w d^2}{4}$$

$$W_{pl,z} = \frac{2t_f b^2}{4} + \frac{dt_w^2}{4}$$

3.3 STEEL SECTIONS
3.4 SECTION PROPERTIES

Buckling parameter (*U*)

$$U = \left(\frac{W_{pl,y}\,g}{A}\right)^{0.5} \times \left(\frac{I_z}{I_w}\right)^{0.25}$$



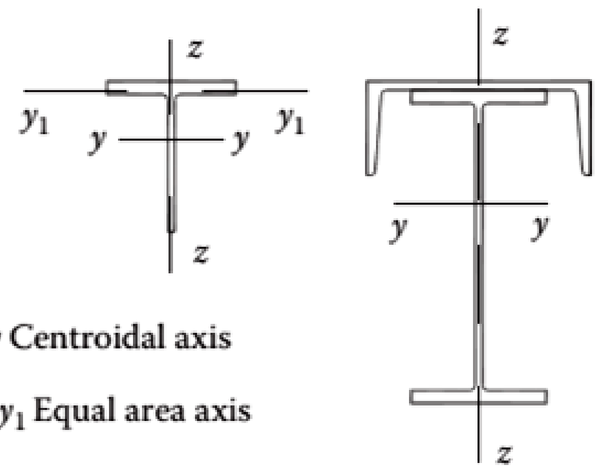
Torsional index (*X*)

$$X = \sqrt{\frac{\pi^2 E A I_w}{20 G I_T I_z}}$$

Warping constant (I_W)

$$I_w = \frac{I_z h_s^{\,2}}{4}$$

Torsional constant (I_T)



$$I_T = \frac{2}{3} b t_f^{\,3} + \frac{1}{3}(h - 2t_f)t_w^{\,3} + 2\alpha_1 D_1^{\,4} - 0.420 t_f^{\,4}$$

$$g = \sqrt{1 - \frac{I_z}{I_y}}\,, \quad G = \frac{E}{2(1+\nu)}$$

$$D_1 = \frac{(t_f + r)^2 + (r + 0.25\,t_w)\,t_w}{2r + t_f}$$

$$\alpha_1 = -0.042 + 0.2204\,\frac{t_w}{t_f} + 0.1355\,\frac{r}{t_f} - 0.0865\,\frac{r t_w}{t_f^{\,2}} - 0.0725\,\frac{t_w^{\,2}}{t_f^{\,2}}$$

h_s is the distance between shear centres of flanges (i.e. $h_s = h - t_f$)