

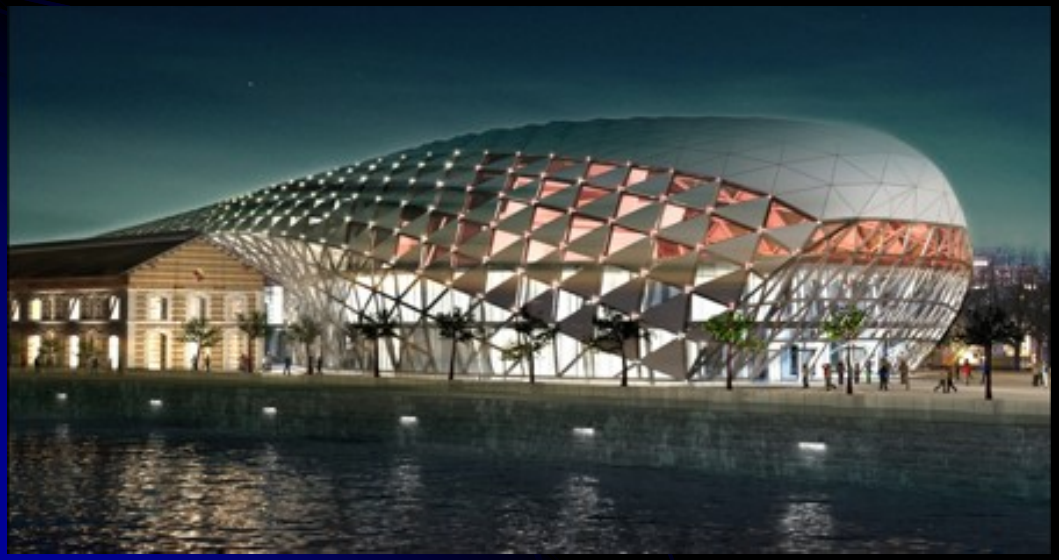
Design of structures

STEEL STRUCTURES

EIFFEL TOWER, PARIS
(1889, Worlds Fair)

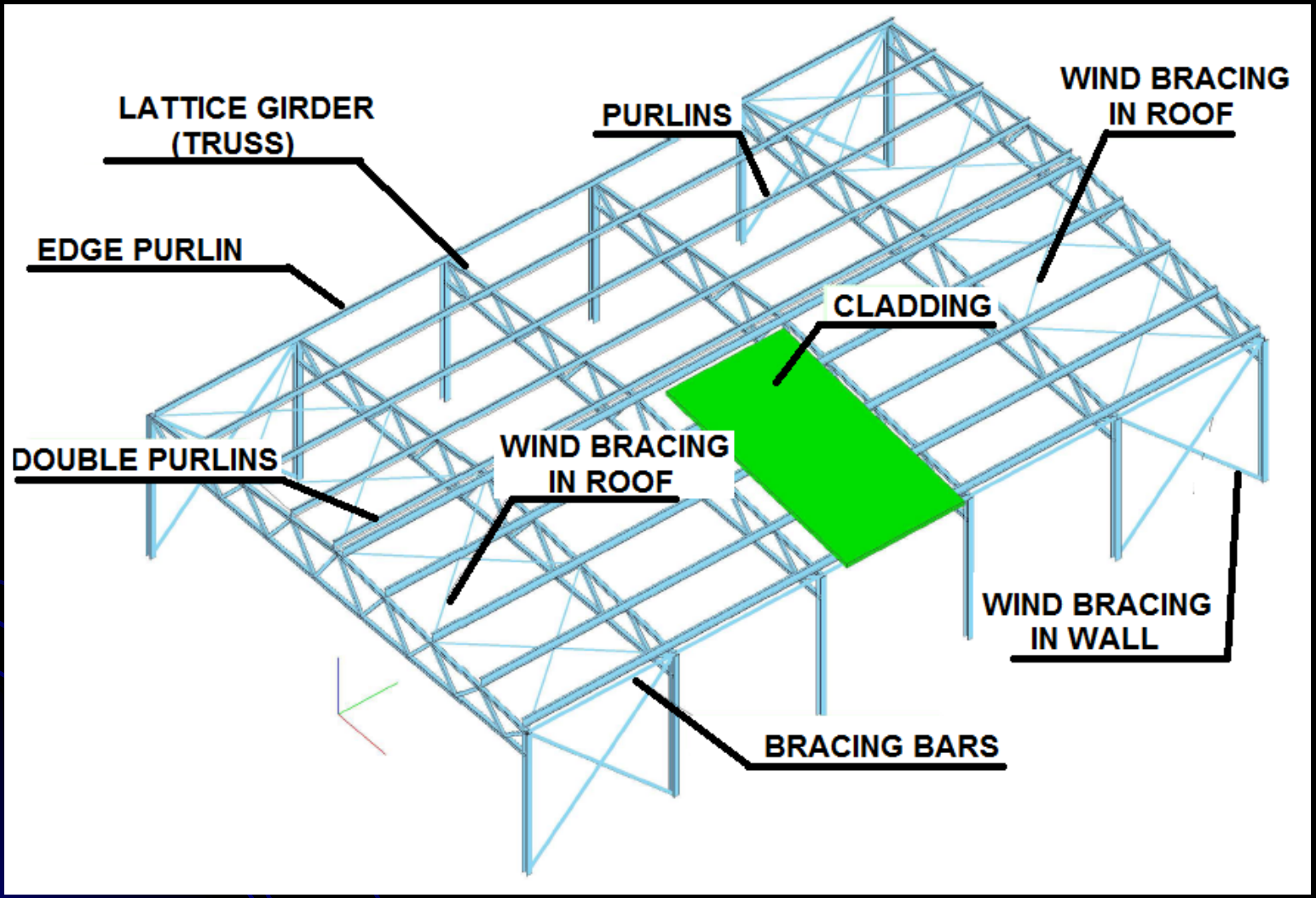
ORANGERY, SCHÖNBRUNN, VIENNA

STEEL STRUCTURES



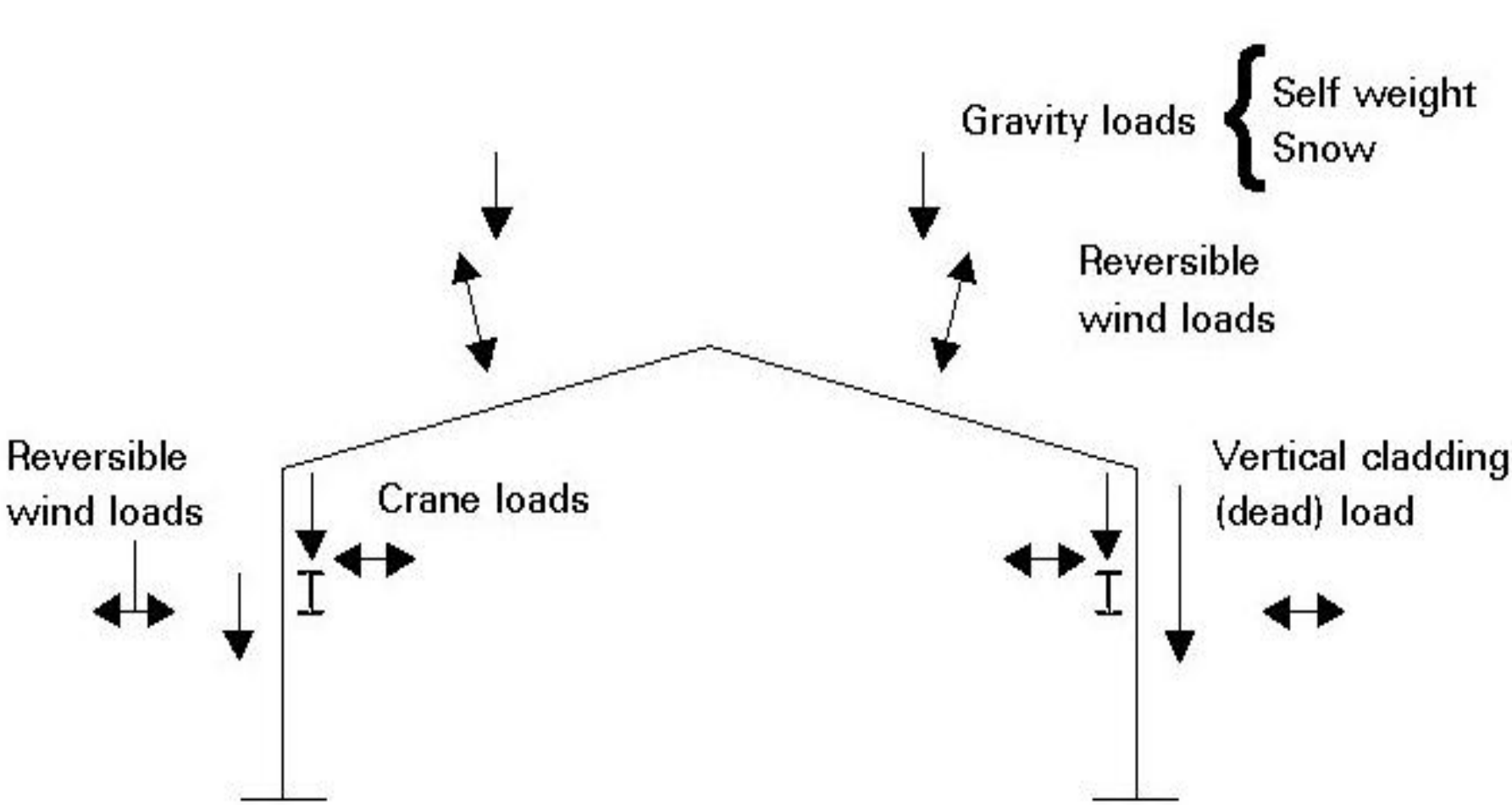
CAPITAL GATE, ABU DHABI

LAKE SHORE DRIVE APARTMANS, CHICAGO



STRUCTURAL MEMBERS OF A SIMPLE HALL CONSTRUCTION 1.

IN PLANE FRAME LOADS



Adventages of steel I. :

- high strength to weight ratio

  (the weight of steel structure will be small)
- big toughness

  (steel has both strength and ductility)
- elasticity big modulus of elasticity

  (follows Hook’s law very accurately)
- consistent material quality

  (properties of steel do not change)

Adventages of steel II. :

- big ductility

  (steel can withstand extensive deformation under tensile stresses without failure, warning before failure)
- strength and deformation properties can be controlled within wide limits
- easy formability

  (malleable, rollable, can be pull, pourable)

Adventages of steel III. :

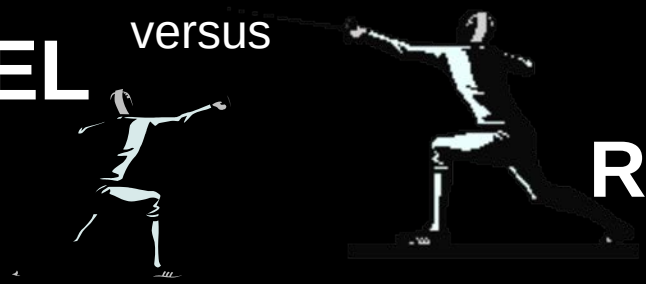
- easy workability
  (drillable, can be cut, can be sawn, machinable, weldable,)
- can be use both for pull and pressure
- hihg resistance against beats and repeated stresses

STEEL

CONCRETE,
REINFORCED CONCRETE
BRICK, STONE

- for same load bearing capacity smaller weight
- lower overall height,
- larger span
- due to plastic overplus it better stand the earthquake
- production can be mechanized
- converible, expandable, relocateble
- easy to strengthen
- easy to unbuild and recyclable
- easy to prefabricated, fast to assemnble, require little propping

STEEL versus CONCRETE, REINFORCED CONCRETE BRICK, STONE



- due to action of **rust** in steel (high maintenance cost)

  average condition 0,1-0,2 mm/year,
  unfavorable condition 1 mm/year

(expensive paints are required to renew time to time)

- very small resistance against fire (600-700 C°)

- relatively expensive building material (require ecconomic design)

Steel

- **Steel is an alloy of iron, carbon and other elements.**
- **It is metallurgical product.**
- ***It is hot rollable, malleable industrial iron alloy.***
- **Usually the slightly alloyes materials with carbon content under 1.7 % are malleable in high temperature so it is considered steel (carbon content is usually under 0.3 %).**

The required properties

- easy formability and workability
- hot malleable, rollable, can be cut, machinable
- be plastic
- high strength (the quality is influenced by the chemical composition)

ALLOYING AND POLLUTER:

- **Most common chemical elements as polluter**:

  oxygen, nitrogen, hydrogen, sulfur, phosporus, copper, (too much carbon), (too muvch silicon)

- **Most common chemical elements as alloying**:

  carbon, manganese, szilicon, nickel, chromium, wolfram, molibdenum, vanadium, titanium

ALLOYING: **CARBON**

INCREASE OF CARBON CONTENT

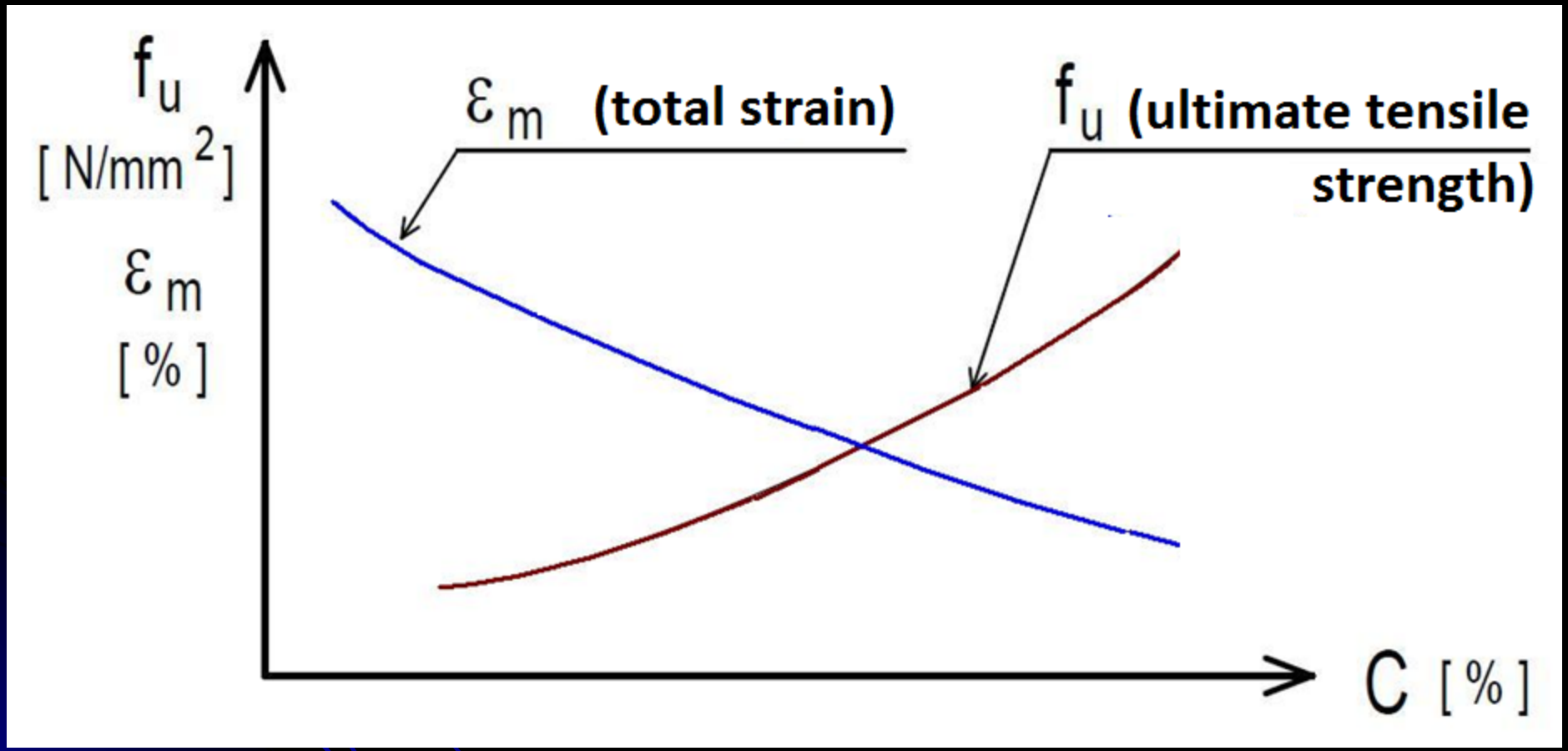
INCREASE THE:

- strength,
- hardness,
- abrasion resistance,
- edzhetősége.

OF THE STEEL.

REDUCE THE :

- ductility,
- cold and hot formabilty,
- weldability,
- machinability,
- resistance against corrosion



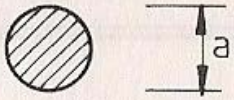
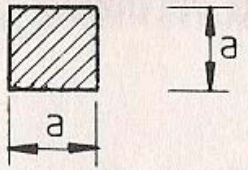
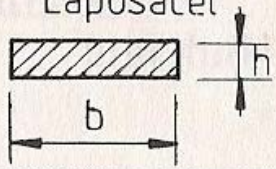
The effect of the carbon content at the steel properties

ROLLED PRODUCTS:

- hot rolled products
  - steel bars,
  - wire rods,
  - steel sections,
  - plates and coils,
  - rolled hollow sections,
  - other rolled sections.
- cold rolled products

STEEL BARS

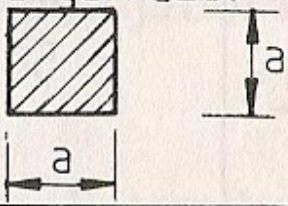
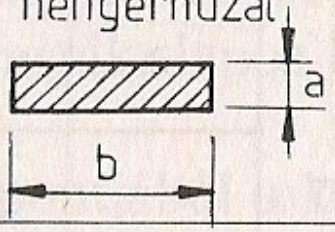
- produced for further processing (intermediers)
- long, straight pieces
- reinforcing rad (in RC), mechanical raw material, bolts, wires

Megnevezés és alak	Méret [mm]			
	Leg-kisebb		Leg-nagyobb	
Köracél 	a		a	
	7		180	
Négyzetacél 	a		a	
	6		60	
Hatszögacél 	a		a	
	10		48	
Laposacél 	b	h	b	h
	10	3	140	50

More important steel bars [2]

WIRE RODS

- produced for further processing (intermediers)
- reinforcing rad (in RC), nail, wire, cable
- rolled deliver

Megnevezés és alak	Méret [mm]	
	Leg-kisebb	Leg-nagyobb
Kör keresztmetszetű hengerhuzal 	a	a
	5,5	15
Négyzetes hengerhuzal 	a	a
	6	11
Lapos hengerhuzal 	a b	a b
	10 4	20 12

More important wire rods [2]

STEEL SECTIONS

- usually designated by the shapes of the cross section
- the traditional cross section types lost their importance after the spread of welding
- wide flange cross sections are wide spread (e.g: HEA400)

Megnevezés és alak	Méret [mm]						Szabvány száma
	Legkisebb			Legnagyobb			
Egyenlőszárú L-acél	a		t	a		t	MSZ 328
	20		3	200		20	
Egyenlőtlenszárú L-acél	a	b	t	a	b	t	MSZ 329
	25	40	4	100	150	14	
U-acél	a		b	a		b	MSZ 326
	50		38	300		100	
I-acél	a		b	a		b	MSZ 325
	80		42	400		155	
Magasgerincű T-acél	a		t	a		t	MSZ 324
	20		3	75		8	
Z-acél	a		b	a		b	MSZ 4311
	30		15	60		50	

Traditional steel sections [2]

TRADITIONAL I SECTION

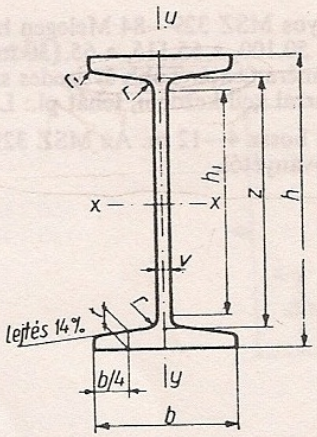
I-szelvény

MSZ 325—51

Megnevezés:

Pl. a 260 mm magas I-szelvény megnevezése:

I 260 MSZ 325

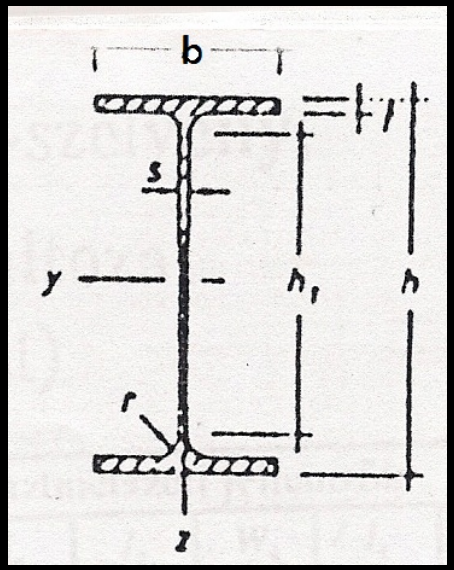


S_x a félszelvény statikai nyomatéka az x—x súlyponti tengelyre. $z = J_x/S_x$ a belső erők karja, a nyomó- és húzófeszültségek eredőinek távolsága.

Méretek						A	G	x—x tengelyre				
h	h_1	b	$v=r$	t	r_1			J_x	W_x	i_x	S_x	z
mm						cm^2	kg/m	cm^4	cm^3	cm	cm^3	cm
80	59	42	3,9	5,9	2,3	7,57	5,94	77,8	19,3	3,20	11,4	6,8
100	76	50	4,5	6,8	2,7	10,6	8,34	171	34,2	4,01	19,9	8,5
120	92	58	5,1	7,7	3,1	14,2	11,1	328	54,7	4,81	31,8	10,3
140	109	66	5,7	8,6	3,4	18,2	14,3	573	81,9	5,61	47,7	12,0
160	126	74	6,3	9,5	3,8	22,8	17,9	935	117	6,40	68,0	13,7
180	142	82	6,9	10,4	4,1	27,9	21,9	1 450	161	7,20	93,4	15,5
200	159	90	7,5	11,3	4,5	33,4	26,2	2 140	214	8,00	125	17,2
220	176	98	8,1	12,2	4,9	39,5	31,1	3 060	278	8,80	162	18,9
240	192	106	8,7	13,1	5,2	46,1	36,2	4 250	354	9,59	206	20,6
260	209	113	9,4	14,1	5,6	53,3	41,9	5 740	442	10,4	257	22,3
280	225	119	10,1	15,2	6,1	61,0	47,9	7 590	542	11,1	316	24,0
300	242	125	10,8	16,2	6,5	69,0	54,2	9 800	653	11,9	381	25,7
320	258	131	11,5	17,3	6,9	77,7	61,0	12 510	782	12,7	457	27,4
340*	274	137	12,2	18,3	7,3	86,7	68,0	15 700	923	13,5	540	29,1
360	290	143	13,0	19,5	7,8	97,0	76,1	19 610	1090	14,2	638	30,7
380*	307	149	13,7	20,5	8,2	107	84,0	24 010	1260	15,0	741	32,4
400	323	155	14,4	21,6	8,6	118	92,4	29 210	1460	15,7	857	34,1

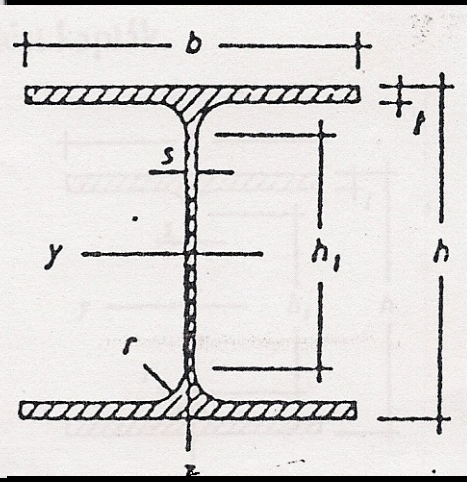
[4]

IPE	méretek						statikai adatok									
	h	b	s	t	r	h_1	A	I_y	W_y	i_y	I_z	W_z	i_z	S_y	s_y	g
	mm	mm	mm	mm	mm	mm	cm^2	cm^4	cm^3	cm	cm^4	cm^3	cm	cm^3	cm	kN/m
80	80	46	3,8	5,2	5	59	7,64	80,1	20,0	3,24	8,49	3,69	1,05	11,6	6,90	0,060
100	100	55	4,1	5,7	7	74	10,3	171	34,2	4,07	15,9	5,79	1,24	19,7	8,68	0,081
120	120	64	4,4	6,3	7	93	13,2	318	53,0	4,90	27,7	8,65	1,45	30,4	10,5	0,104
140	140	73	4,7	6,9	7	112	16,4	541	77,3	5,74	44,9	12,3	1,65	44,2	12,3	0,129
160	160	82	5,0	7,4	9	127	20,1	869	109	6,58	68,3	16,7	1,84	61,9	14,0	0,158
180	180	91	5,3	8,0	9	146	23,9	1320	146	7,42	101	22,2	2,05	83,2	15,8	0,188
200	200	100	5,6	8,5	12	159	28,5	1940	194	8,26	142	28,5	2,24	110	17,6	0,224
220	220	110	5,9	9,2	12	177	33,4	2770	252	9,11	205	37,3	2,48	143	19,4	0,262
240	240	120	6,2	9,8	15	190	39,1	3890	324	9,97	284	47,3	2,69	183	21,2	0,307
270	270	135	6,6	10,2	15	219	45,9	5790	429	11,2	420	62,2	3,02	242	23,9	0,361
300	300	150	7,1	10,7	15	248	53,8	8360	557	12,5	604	80,5	3,35	314	26,6	0,422
330	330	160	7,5	11,5	18	271	62,6	11770	713	13,7	788	98,5	3,55	402	29,3	0,491
360	360	170	8,0	12,7	18	298	72,7	16270	904	15,0	1040	123	3,79	510	31,9	0,571
400	400	180	8,6	13,5	21	331	84,5	23130	1160	16,5	1320	146	3,95	654	35,4	0,663
450	450	190	9,4	14,6	21	378	98,8	33740	1500	18,5	1680	176	4,12	851	39,7	0,776
500	500	200	10,2	16,0	21	426	116	48200	1930	20,4	2140	214	4,31	1100	43,9	0,907
550	550	210	11,1	17,2	24	467	134	67120	2440	22,3	2670	254	4,45	1390	48,2	1,06
600	600	220	12,0	19,0	24	514	156	92080	3070	24,3	3390	308	4,66	1760	52,4	1,22



IPE SECTIONS

IPBl HE-A	Méretek						Keresztmetszeti jellemzők									
	h mm	b mm	s mm	t mm	r mm	h_1 mm	A cm²	I_y cm⁴	W_y cm³	i_y cm	I_z cm⁴	W_z cm³	I/i_z cm	S_y cm³	s_y cm	g kN/m
100	96	100	5	8	12	56	21,2	349	72,8	4.06	134	26,8	2,51	41.5	8,41	0.167
120	114	120	5	8	12	74	25.3	606	106	4,89	231	38,5	3,02	59.7	10,1	0.199
140	133	140	5,5	8.5	12	92	31.4	1030	155	5,73	389	55,6	3.52	86.7	11,9	0.247
160	152	160	6	9	15	104	38,8	1670	220	6.57	616	76,9	3,98	123	13,6	0,304
180	171	180	6	9,5	15	122	45.3	2510	294	7.45	925	103	4,52	162	15,5	0.355
200	190	200	6,5	10	18	134	53,8	3690	389	8,28	1340	134	4,98	215	17,2	0.423
220	210	220	7	11	18	152	64.3	5410	515	9.17	1950	178	5,51	284	19,0	0.505
240	230	240	7.5	12	21	164	76.8	7760	675	10.1	2770	231	6.00	372	20.9	0.603
260	250	260	7,5	12,5	24	177	86.8	10450	836	11,0	3670	282	6.50	460	22,7	0.682
280	270	280	8	13	24	196	97,3	13670	1010	11,9	4760	340	7.00	556	24,6	0.764
300	290	300	8,5	14	27	208	113	18260	1260	12.7	6310	421	7,49	692	26.4	0.883
320	310	300	9	15.5	27	225	124	22930	1480	13.6	6990	466	7,49	814	28.2	0.976
340	330	300	9,5	16.5	27	243	133	27690	1680	14.4	7440	496	7,46	925	29.9	1.05
360	350	300	10	17,5	27	261	143	33090	1890	15.2	7890	526	7,43	1040	31.7	1.12
400	390	300	11	19	27	298	159	45070	2310	16.8	8560	571	7,34	1280	35.2	1.25
450	440	300	11.5	21	27	344	178	63720	2900	18.9	9470	631	7.29	1610	39.6	1.40
500	490	300	12	23	27	390	198	86970	3550	21.0	10370	691	7,24	1970	44.1	1.55
550	540	300	12,5	24	27	438	212	111900	4150	23.0	10820	721	7,15	2310	48.4	1.66
600	590	300	13	25	27	486	226	141200	4790	25.0	11270	751	7,05	2680	52.8	1.78
650	640	300	13.5	26	27	534	242	175200	5470	26.9	11720	782	6.97	3070	57.1	1.90
700	690	300	14,5	27	27	582	260	215300	6240	28.8	12180	812	6,84	3520	61.2	2,04
800	790	300	15	28	30	674	286	303400	7680	32.6	12640	843	6,65	4350	69.8	2.24
900	890	300	16	30	30	770	321	422100	9480	36.3	13550	903	6,50	5410	78.1	2.52
1000	990	300	16,5	31	30	868	347	553800	11190	40.0	14000	934	6,35	6410	86.4	2.72



WIDE FLANGE I SECTIONS (HEA)

PLATES AND COILS

- pates are deliver as straight element while coils are deliver rolled
- thickness of plates (t) are beetwen 3 and 60 mm, the width (s) are beetwen 500 and 2500 mm.

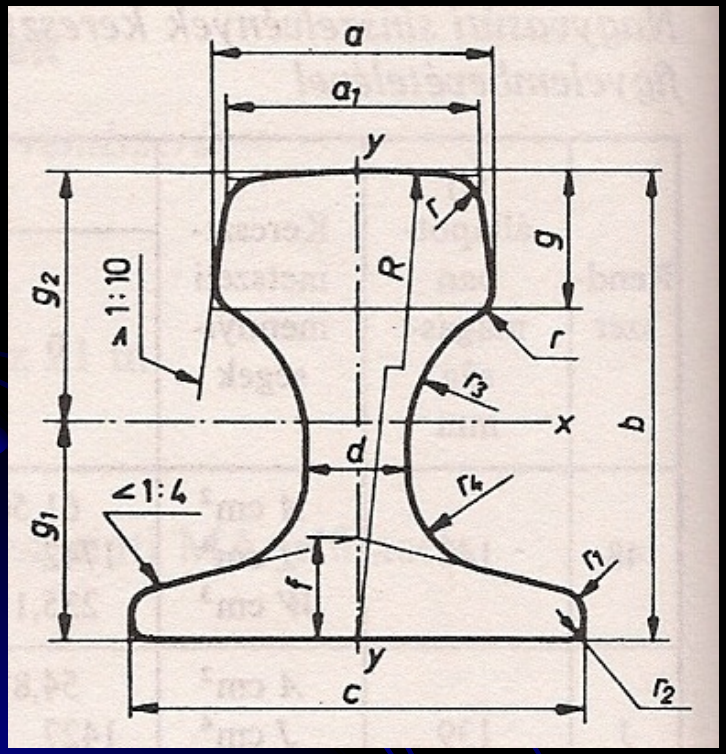
Grouping of plates:

thin plate	t < 3 mm	s = 10 -140 mm	(flat steel)
medium plate	t = 3 - 7 mm	s = 150 - 500 mm	(wide steel)
thick plate	t > 7 mm	s = 500 - 2000 mm	(plate)

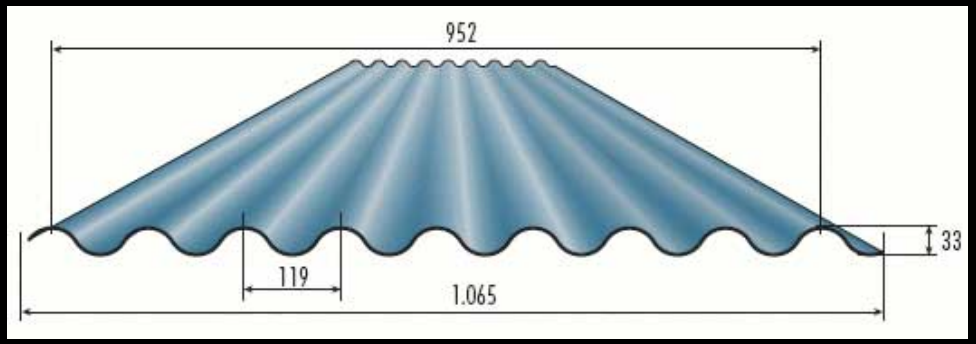
Grouping of coils:

narrow coil	s < 60 mm
wide coil	s > 60 mm

OTHER ROLLED SECTIONS



Crane rails [4]

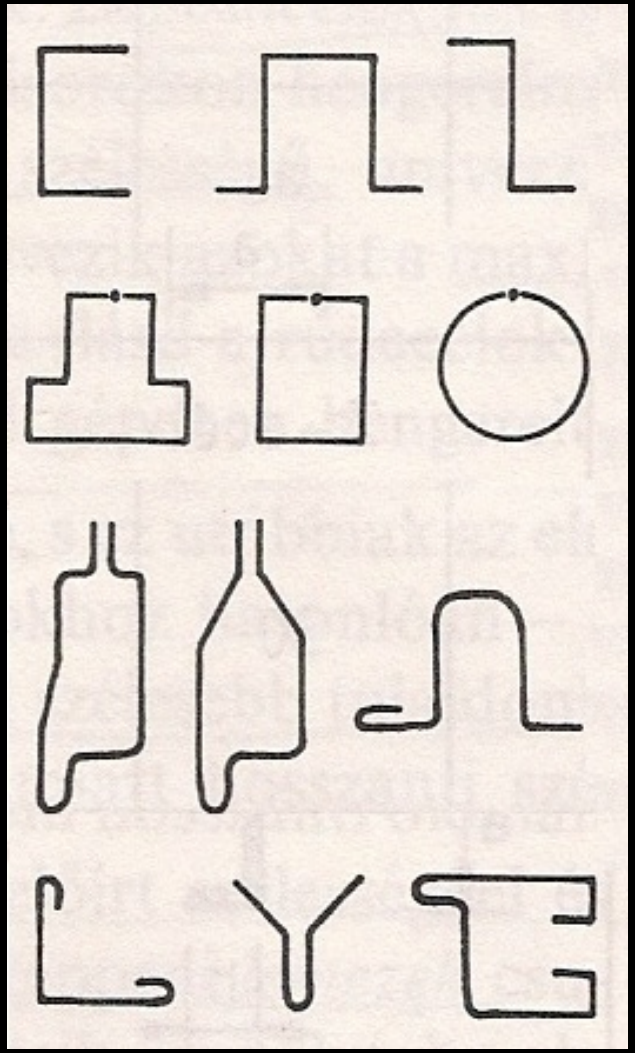


Corrugated sheet

COLD ROLLED CROSS SECTIONS

- if special shape cross section
- thin gauge cross section

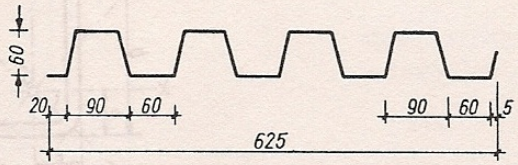
From small carbon content plate bars or from coils (fabrication with cold bending)



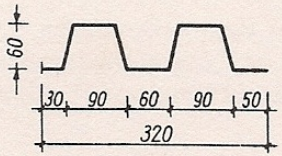
Thin gauge sections [2]

Trapezoidal steel sheet [4]

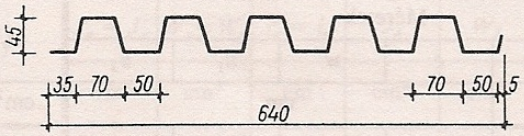
DV–1–HT jelű



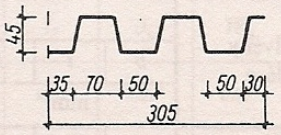
DV–1/2–HT jelű



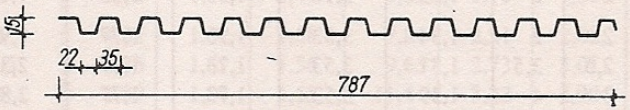
DV–2–HT jelű



DV–2/2–HT jelű

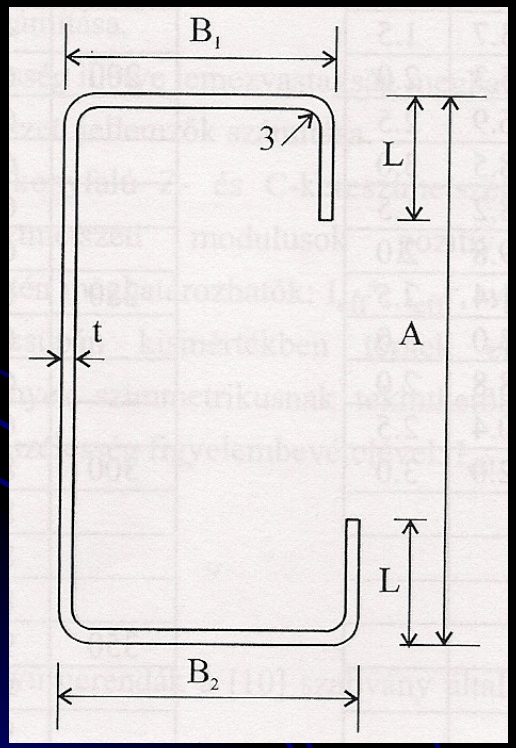


DV–5–HT jelű

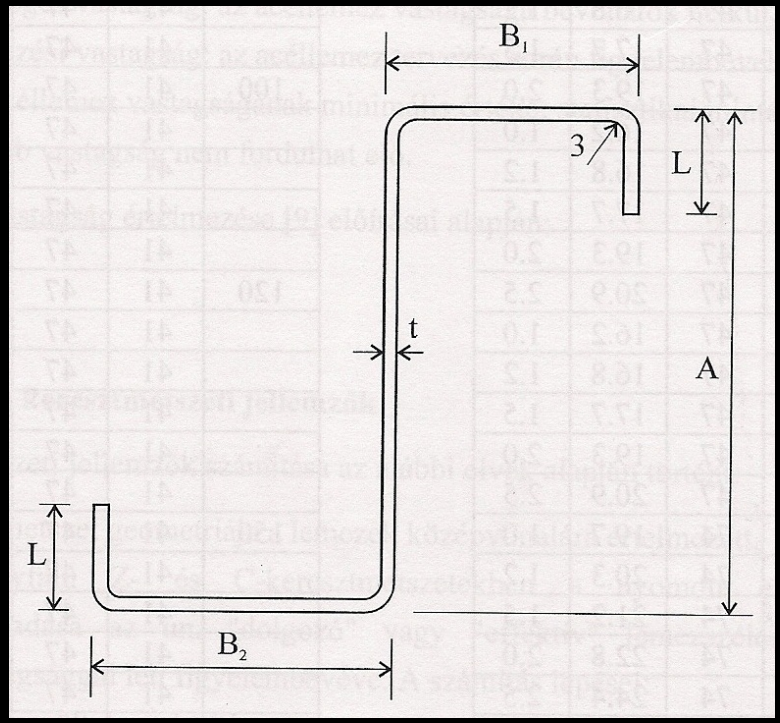


Jelölés	t	A	G	J	W	σ_H
	mm	cm^2/m	kg/m^2	cm^4/m	cm^3/m	N/mm^2
DV–1–HT	0,8	13,20	10,36	77,5	25,4	78
	1,0	16,50	12,95	96,9	31,7	95
	1,25	20,63	16,19	121,3	39,6	107
	1,5	24,75	19,43	137,0	44,8	110
DV–2–HT	0,8	13,28	10,42	41,1	17,9	92
	1,0	16,60	13,03	51,4	22,3	106
	1,25	20,75	16,29	64,3	27,9	115
DV–5–HT	0,5	6,75	5,30	2,40	3,38	112
	0,75	10,13	7,95	3,97	5,41	120
	1,0	13,50	10,60	4,84	6,76	120

LINDAB thin gauge
C- and Z-elements

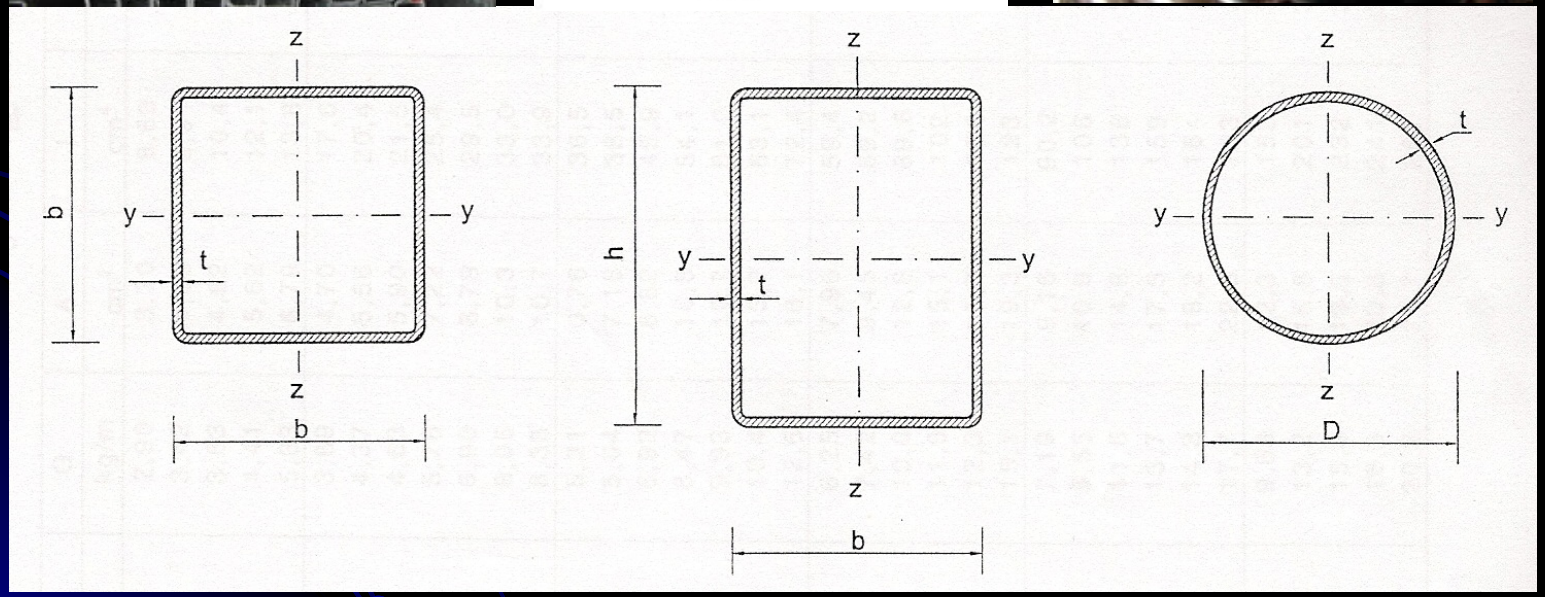


C-profile



Z-profile

EUROPEAN HOLLOW SECTIONS



SHS **RHS** **CHS**

THE YIELD STRENGTH AND ULTIMATE TENSILE STRENGTH FOR STRUCTURAL STEEL **[3]**

$t \leq 40$ mm ?

$40 \text{ mm} \leq t \leq 80$ mm ?

$$\frac{f_y}{f_u} \approx \frac{2}{3}$$

S 235

S 275

S 355

Acélfajta jele	A szerkezeti elem névleges vastagsága t [mm]			
	$t \leq 40$ mm		40 mm < t ≤ ≤ 80 mm	
	f_y	f_u	f_y	f_u
EN 10025				
S 235	235	360	215	360
S 275	275	430	255	410
S 355	355	510	335	470
S 450	440	550	410	550
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
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
EN 10210-1				
S 235 H	235	360	215	340
S 275 H	275	430	255	410
S 355 H	355	510	335	490
S275NH/NHL	275	390	255	370
S355NH/NHL	355	490	335	470
EN 10219-1				
S 235 H	235	360		
S 275 H	275	430		
S 355 H	355	510		
S275NH/NHL	275	370		
S355NH/NHL	355	470		

SOME CHARACTERISTICS OF STRUCTURAL STEEL :

- modulus of elasticity : 210000 N/mm^2
- ultimate strain : 18-30 %
- Brinell-hardness number: 1000-2000 N/mm^2
- coefficient of thermal expansion (CTE): $1,2 \cdot 10^{-5}$ 1/C°
- density: 7850 kg/m^3

Szabvány		C max % névleges vastagság (mm)			Mn max %	Si max %	P max %	S max %	N max %	Al[1] max %	Nb max %	V max %	CEV [7] max %			
		≤16	>16 ≤40	>40									≤16	>16 ≤40	>40 ≤63	>63 ≤150
EN 10025: 1993 [6]	S235 JRG2	0,17	0,17	0,20	1,4	-	0,045	0,045	0,009 [4] [5]				0,35	0,35	0,38	0,38
	S235 J0	0,17	0,17	0,17	1,4	-	0,040	0,040	0,009 [4] [5]				0,35	0,35	0,38	0,38
	S275 JR	0,21	0,21	0,22	1,5	-	0,045	0,045	0,009 [4] [5]				0,40	0,40	0,42	0,42
	S275 J0	0,18	0,18	0,18	1,5	-	0,040	0,040	0,009 [4] [5]							
	S355 JR	0,24	0,24	0,24	1,6	0,55	0,045	0,045	0,009 [4] [5]				0,45	0,45	0,47	0,47
	S355 J0	0,20	0,20	0,22	1,6	0,55	0,040	0,040	0,009 [4] [5]				0,45	0,45	0,47	0,47
	S355 J2G3/G4	0,20	0,20	0,22	1,6	0,55	0,035	0,035	-				0,45	0,45	0,47	0,47
	S355 K2G3/G4	0,20	0,20	0,22	1,6	0,55	0,035	0,035	-				0,45	0,45	0,47	0,47
EN 10113-3: 1993 [2]	S 355 M	0,16	0,16	0,16	1,6	0,50	0,035	0,030	0,015	0,02	0,05	0,010	0,39	0,39	0,40	0,45
	S 355 ML	0,16	0,16	0,16	1,6	0,50	0,030	0,025	0,015	0,02	0,05	0,010	0,39	0,39	0,40	0,45
	S 420 M	0,18	0,18	0,18	1,7	0,50	0,035	0,030	0,020	0,02	0,05	0,012	0,43	0,45	-	-
	S 420 ML	0,18	0,18	0,18	1,7	0,50	0,030	0,025	0,020	0,02	0,05	0,012	0,43	0,45	-	-
	S 460 M	0,18	0,18	0,18	1,7	0,60	0,035	0,030	0,025	0,02	0,05	0,012	0,45	0,46	-	-
	S 460 ML	0,18	0,18	0,18	1,7	0,60	0,030	0,025	0,025	0,02	0,05	0,012	0,45	0,46	-	-

Chemical composition of structural steel [1]

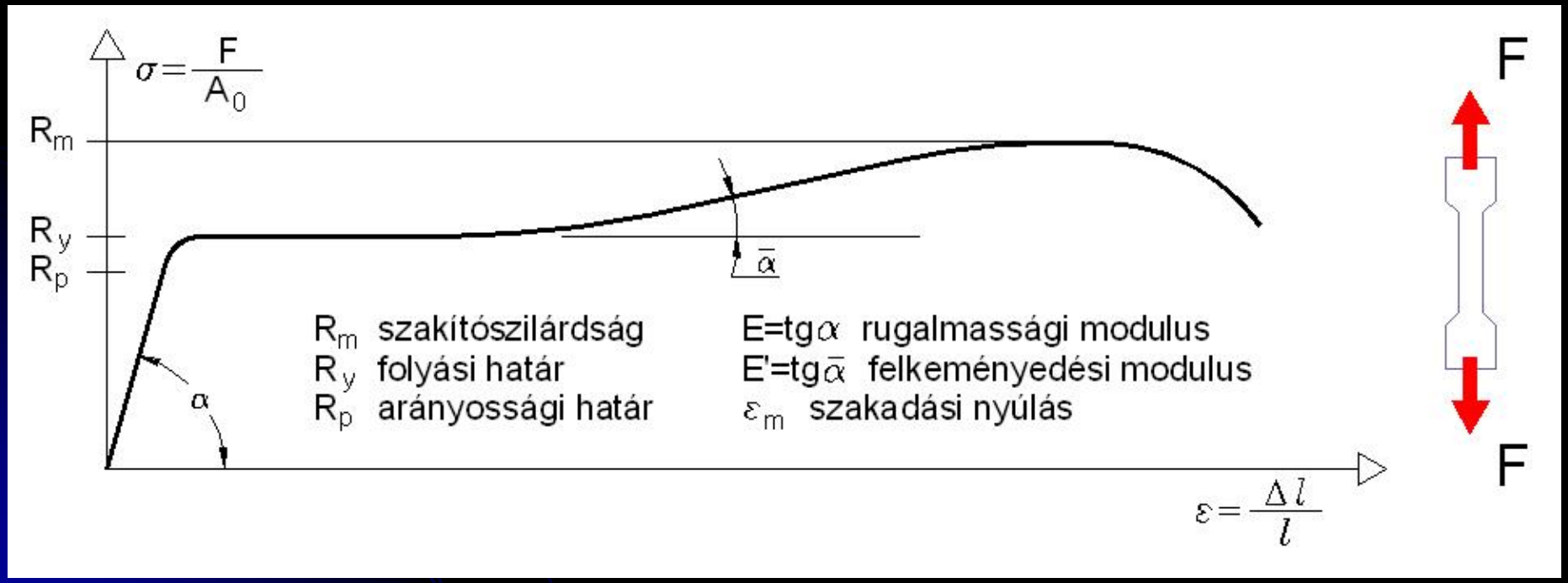
❑ Stress-strain diagram:

Represent the connection between stress and strain.

- tension stress-strain diagram
- shear stress-strain diagram
- compression stress-strain diagram

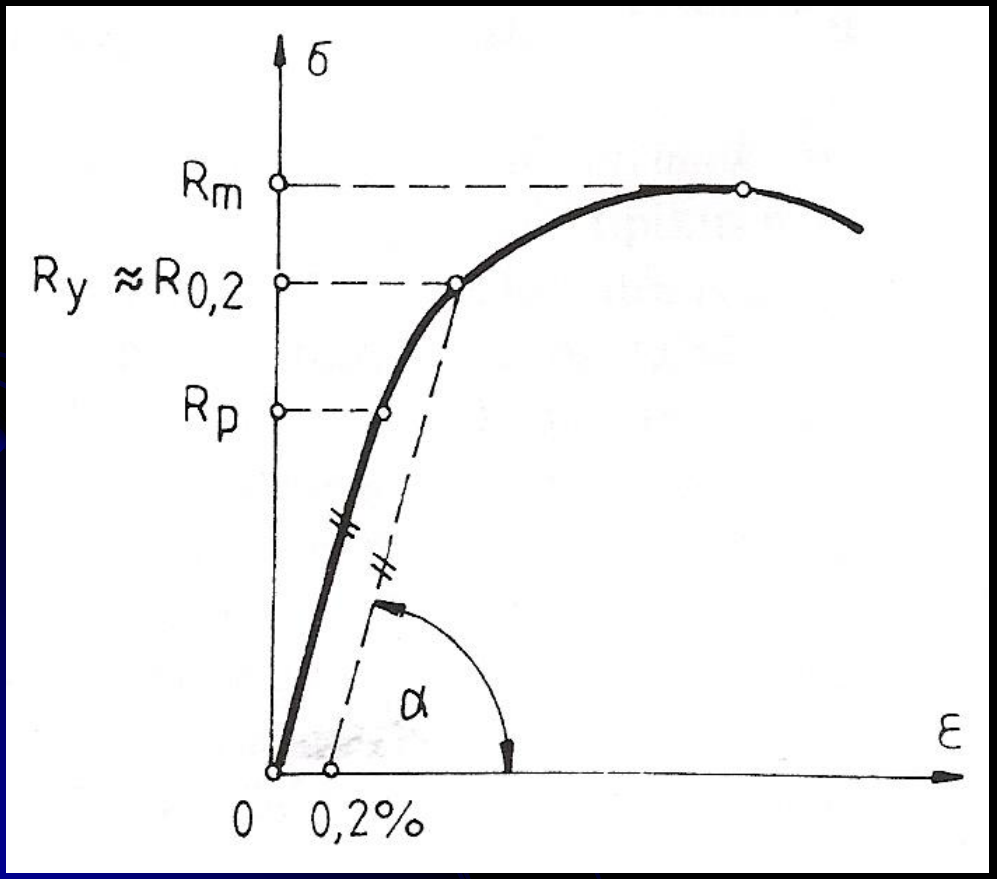
❑ tension stress-strain diagram in case of structural steel (ductile material)

-Less strength, large strain, steel with good ductile properties (f_u = 300-500 N/mm^2 $\varepsilon_u \approx$ 20 %, c < 0,1-0,4 %)



Stress-strain diagram of structural steel [1]

❑ Stress-strain diagram in case of high strength steel:



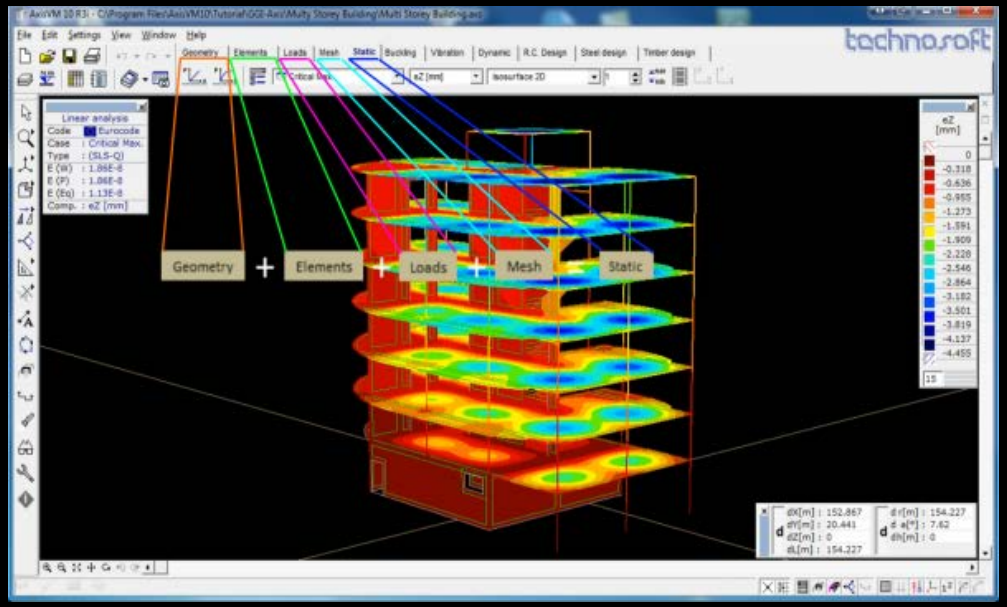
-No or short yield sections

- conventional yield point

(the stress which belongs to the 0,2 % residual strain

Stress-strain diagram in case of high strength steel [2]

CHECKING OF STEEL STRUCTURES



DESIGN:

- New structure
- Static system
- Cross-sectional sizes
- Connections
- Customer interest

CHECKING:

- Existing or designed construction
- Verify the rightness of the structural elements and connections

PARCELLING THE STRUCTURE