

### U/A ratio [min-1]

Protection is generally necessary to ensure that steel structural elements only heat up to a temperature less than the critical temperature in the fire case. The critical temperature is the temperature at which the proof stress of the steel falls to the stress pertaining in the structural element. It is calculated on the basis of the U/A ratio. The section factor is of major importance for the heating up of a steel structure exposed to fire. According to EC3-1-2, the section factor  $A_m/V$  is defined as the ratio of the surface area exposed to the fire to the volume of the steel structural element. For structural elements with a constant cross-section along their whole length, the section factor is identical to the value of U/A according to DIN 4102 Part 4. The larger this factor, the quicker the section heats up. Accordingly, a slender IPE section heats up more rapidly than a more solid section with a low section factor.

The necessary minimum thickness for the fire protection material selected depends on the fire resistance class required. Material thicknesses are given either in DIN 4102 Part 4 or in the manufacturer's brochures. These values are based on standard fire tests. As a general rule: the weaker the section, the thicker the cladding has to be in order to achieve the fire resistance demanded.

According to Eurocode 3 Part 10 or Part 1.2, one differentiates between:

- a cross-section factor  $A_m/V$  for unprotected steel structural elements
- a cross-section factor  $A_p/V$  for protected steel structural elements.

Besides the definition 'area exposed to the flames divided by the cross-section to be heated up', the formula

$100 / t$  where  $t$  = sheet thickness in cm

plays an important role in the calculation of U/A. According to DIN 4102 Part 4 and the Eurocode versions e.g. for four-sided hollow sections exposed to flames with profile protection or for appropriate sections without a casing. Even when there is flame impingement on one side, as is the case with I-sections that are walled-in or encased in concrete or with vaulted ceilings, the formula should be used for the exposed flange.

### Formulae for determining the U/A ratio:

#### Four-sided box protection:

$$U/A = \frac{2h+2b}{A} \cdot 100 = (\text{m}^{-1})$$

#### Three-sided box protection:

$$U/A = \frac{2h+b}{A} \cdot 100 = (\text{m}^{-1})$$

#### Key:

U = circumference of steel section in cm

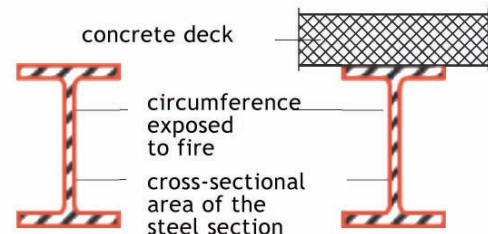
A = cross-sectional area of steel section in  $\text{cm}^2$

h = height of section

b = width of section

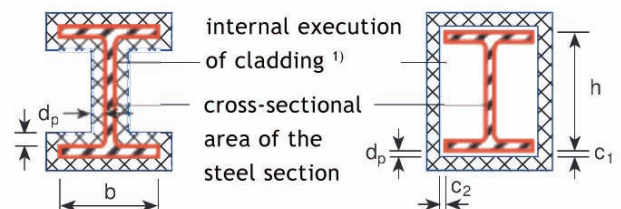
### Section factors for unprotected steel members

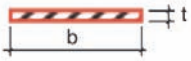

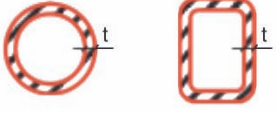
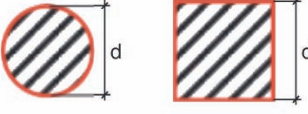
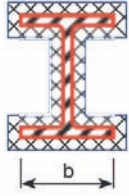
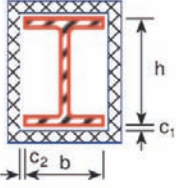
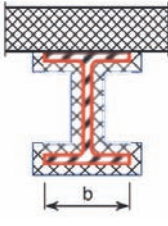
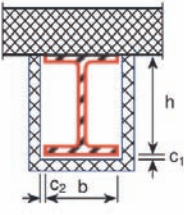
Section factor:  $\frac{A_m}{V} = \frac{\text{circumference exposed to fire}}{\text{cross-sectional area of steel section}}$




### Section factors for clad steel members

Section factor:  $\frac{A_m}{V} = \frac{\text{internal execution of cladding}}{\text{cross-sectional area of steel section}}$







Shape of cross-section (examples)	$A_m/V$
Flat steel bar 	Fire exposure: all sides = $2/t$ one-sided = $1/t$
Open cross-sections constant wall thickness 	Fire exposure: all sides = $2/t$
Hollow sections (round and rectangular) 	Fire exposure: all sides (outside) = $1/t$
Solid steel (round or square) 	Fire exposure: all sides = $4/d$
Profile protection of constant thickness 	Profile protection: circumference <u>steel section</u> cross-sectional area of steel
Box protection <sup>1)</sup> of constant thickness 	Box protection: $2(b+h)^1$ Cross-sectional area of steel
Cross-sectional area of steel Profile protection of constant thickness, three-sided exposure to fire 	Profile protection: Circumference <u>steel section</u> – <u>b</u> Cross-sectional area of steel
Box protection <sup>1)</sup> of constant thickness, three-sided exposure to fire 	Box protection: $(2h+b)^1$ Cross-sectional area of steel





<sup>1)</sup> The air gaps  $c_1$  and  $c_2$  should not exceed  $h/4$






 Insulation (thickness  $d_p$ )  





 Cross-sectional area of steel





### Section factors $A_m/V$





HEA				
HP 200 x 43	181	219	112	150
HP 200 x 53	145	176	90	121
HP 220 x 57,2	143	174	88	119
HP 260 x 75	129	156	80	108
HP 260 x 87,3	111	135	70	94
HP 305 x 79	147	178	91	121
HP 305 x 88	132	159	81	109
HP 305 x 95	122	148	76	101
HP 305 x 110	106	129	66	88
HP 305 x 126	94	113	58	78
HP 305 x 149	80	97	50	67
HP 305 x 180	67	81	42	56
HP 305 x 186	65	79	41	55
HP 305 x 223	55	67	35	47
HP 320 x 88,5	128	155	81	108
HP 320 x 103	111	135	70	94
HP 320 x 117	98	119	62	83
HP 320 x 147	80	96	51	68
HP 320 x 184	65	78	42	55
HP 360 x 84,3	162	196	98	132
HP 360 x 109	126	153	77	103
HP 360 x 133	104	126	64	86
HP 360 x 152	92	111	56	76
HP 360 x 174	81	98	50	67
HP 360 x 180	78	95	48	65
HP 400 x 122	116	141	70	95
HP 400 x 140	102	124	61	83
HP 400 x 158	91	111	55	74
HP 400 x 176	82	100	50	67
HP 400 x 194	75	91	46	62
HP 400 x 213	69	84	42	57
HP 400 x 231	64	77	39	53





HEB				
100	180	218	115	154
120	167	202	106	141
140	155	187	98	130
160	140	169	88	118
180	131	159	83	110
200	122	147	77	102
220	115	140	72	97
240	108	131	68	91
260	105	127	66	88
280	102	123	64	85
300	96	116	60	80
320	91	110	58	77
340	88	106	57	75
360	86	102	56	73
400	82	97	56	71
450	79	93	55	69
500	76	89	54	67
550	76	88	55	67
600	75	86	56	67
650	74	85	56	66
700	72	82	55	65
800	72	81	57	66
900	70	78	57	65
1000	70	78	57	65





IPE				
100	334	387	247	300
120	311	360	230	279
140	291	335	215	259
160	269	310	200	241
180	253	291	188	226
200	235	270	176	211
220	221	254	165	198
240	205	236	153	184
270	197	227	147	176
300	188	216	139	167
330	176	200	131	157
360	163	186	122	146
400	152	174	116	137
450	143	162	110	130
500	134	151	104	121
550	124	140	97	113
600	115	129	91	105

IPN				
IPN 120	268	309	210	251
IPN 140	238	274	189	225
IPN 160	220	252	173	205
IPN 180	200	229	158	188
IPN 200	185	212	147	174
IPN 220	171	196	136	161
IPN 240	160	183	127	150
IPN 260	149	170	119	140
IPN 280	139	158	111	131
IPN 300	131	149	105	123
IPN 320	123	140	99	116
IPN 340	117	133	94	110
IPN 360	110	125	89	104
IPN 380	105	119	85	99
IPN 400	100	113	81	94
IPN 450	89	101	73	84
IPN 500	81	91	66	77
IPN 550	75	85	61	71

UPN				
100	239	276	185	222
120	223	255	174	206
140	210	240	167	196
160	200	228	160	188
180	193	218	154	179
200	182	205	148	171
220	171	192	139	160
240	163	183	134	154
260	154	173	126	145
280	149	167	123	141
300	145	162	119	136
320	116	130	98	111
350	123	135	103	116
380	125	138	107	120
400	117	129	99	111

HEM				
100	96	116	65	85
120	92	111	61	80
140	88	106	58	76
160	83	100	54	71
180	80	96	52	68
200	76	92	49	65
220	73	88	47	62
240	61	73	39	52
260	59	72	39	51
280	59	71	38	50
300	50	60	33	43
320	50	60	33	43
340	50	60	34	43
360	51	61	34	44
400	52	62	36	45
450	53	62	38	47
500	55	63	39	48
550	56	64	41	50
600	57	65	42	51
650	58	66	44	52
700	59	67	45	53
800	60	68	48	55
900	70	78	50	57
1000	64	70	52	59

HP				
100	217	264	138	185
120	220	267	137	185
140	208	253	129	174
160	192	234	120	161
180	187	226	115	155
200	174	211	108	145
220	161	195	99	134
240	147	178	91	122
260	141	171	88	117
280	136	165	84	113
300	126	153	78	105
320	117	141	74	98
340	112	134	72	94
360	107	128	70	91
400	101	120	68	87
450	96	113	66	83
500	92	107	65	80
550	90	104	65	79
600	89	102	65	79
650	87	100	65	78
700	85	96	64	76
800	84	94	66	76
900	81	90	65	74
1000	81	89	66	74

HD				
HD 260 x 54,1	176	214	108	146
HD 260 x 68,2	141	171	88	117
HD 260 x 93	105	127	66	88
HD 260 x 114	86	104	55	73
HD 260 x 142	71	86	46	60
HD 260 x 172	59	72	39	51
HD 320 x 74,2	152	184	95	127
HD 320 x 97,6	117	141	74	98
HD 320 x 127	91	110	58	77
HD 320 x 158	74	89	48	63
HD 320 x 198	60	72	39	51
HD 320 x 245	50	60	33	43
HD 320 x 300	42	50	28	36
HD 360 x 134	104	125	63	85
HD 360 x 147	95	114	58	78
HD 360 x 162	87	105	53	71
HD 360 x 179	79	95	49	65
HD 360 x 196	72	87	45	60
HD 400 x 187	78	94	47	64
HD 400 x 216	68	82	42	56
HD 400 x 237	63	76	38	52
HD 400 x 262	57	69	35	47
HD 400 x 287	52	63	32	43
HD 400 x 314	48	58	30	40
HD 400 x 347	44	53	28	37
HD 400 x 382	40	49	25	34
HD 400 x 421	37	45	23	31
HD 400 x 463	34	41	22	29
HD 400 x 509	31	38	20	27
HD 400 x 551	29	35	19	25
HD 400 x 592	28	33	18	23
HD 400 x 634	26	31	17	22
HD 400 x 677	25	30	16	21
HD 400 x 744	23	27	15	20
HD 400 x 818	21	25	14	18
HD 400 x 900	19	23	13	17
HD 400 x 990	18	22	12	16
HD 400 x 1086	17	20	11	15

#### Literature

- DIN 4102  
Fire behaviour of building materials and building components - Part 4:  
Date of publication: 1994-03, Beuth Verlag, Berlin
- DIN V ENV 1993-1-2 Eurocode 3 -  
Design of steel structures - Part 1-2: General rules  
- Structural fire design  
German version ENV 1993-1-2: 1995,  
Date of publication 1997-05, Beuth Verlag, Berlin

#### Expert advice

If you want company-neutral advice, for example at the early draft stage, **bauforumstahl** is at your service and will gladly offer advice and information.

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