

- (5) Rigid plastic analysis may be applied if no effects of the deformed geometry (e.g. second-order effects) have to be considered. In this case joints are classified only by strength, see EN 1993-1-8.
- (6) The effects of deformed geometry of the structure and the structural stability of the frame should be verified according to the principles in 5.2.

NOTE The maximum resistance of a frame with significantly deformed geometry may occur before all hinges of the first order collapse mechanism have formed.

5.5 Classification of cross sections

5.5.1 Basis

- (1) The role of cross section classification is to identify the extent to which the resistance and rotation capacity of cross sections is limited by its local buckling resistance.

5.5.2 Classification

- (1) Four classes of cross-sections are defined, as follows:
- Class 1 cross-sections are those which can form a plastic hinge with the rotation capacity required from plastic analysis without reduction of the resistance.
 - Class 2 cross-sections are those which can develop their plastic moment resistance, but have limited rotation capacity because of local buckling.
 - Class 3 cross-sections are those in which the stress in the extreme compression fibre of the steel member assuming an elastic distribution of stresses can reach the yield strength, but local buckling is liable to prevent development of the plastic moment resistance.
 - Class 4 cross-sections are those in which local buckling will occur before the attainment of yield stress in one or more parts of the cross-section.
- (2) In Class 4 cross sections effective widths may be used to make the necessary allowances for reductions in resistance due to the effects of local buckling, see $\boxed{\text{AC}_2}$ EN 1993-1-5, 4.4 $\boxed{\text{AC}_2}$.
- (3) The classification of a cross-section depends on the width to thickness ratio of the parts subject to compression.
- (4) Compression parts include every part of a cross-section which is either totally or partially in compression under the load combination considered.
- (5) The various compression parts in a cross-section (such as a web or flange) can, in general, be in different classes.
- (6) A cross-section is classified according to the highest (least favourable) class of its compression parts. Exceptions are specified in 6.2.1(10) and 6.2.2.4(1).
- (7) Alternatively the classification of a cross-section may be defined by quoting both the flange classification and the web classification.
- (8) The limiting proportions for Class 1, 2, and 3 compression parts should be obtained from Table 5.2. A part which fails to satisfy the limits for Class 3 should be taken as Class 4.
- (9) Except as given in (10) Class 4 sections may be treated as Class 3 sections if the width to thickness ratios are less than the limiting proportions for Class 3 obtained from Table 5.2 when ε is increased by $\sqrt{\frac{f_y / \gamma_{M0}}{\sigma_{\text{com,Ed}}}}$, where $\sigma_{\text{com,Ed}}$ is the maximum design compressive stress in the part taken from first order or where necessary second order analysis.

(10) However, when verifying the design buckling resistance of a member using section 6.3, the limiting proportions for Class 3 should always be obtained from Table 5.2.

(11) Cross-sections with a Class 3 web and Class 1 or 2 flanges may be classified as class 2 cross sections with an effective web in accordance with 6.2.2.4.

(12) Where the web is considered to resist shear forces only and is assumed not to contribute to the bending and normal force resistance of the cross section, the cross section may be designed as Class 2, 3 or 4 sections, depending only on the flange class.

NOTE For flange induced web buckling see EN 1993-1-5.

5.6 Cross-section requirements for plastic global analysis

(1) At plastic hinge locations, the cross-section of the member which contains the plastic hinge should have a rotation capacity of not less than the required at the plastic hinge location.

(2) In a uniform member sufficient rotation capacity may be assumed at a plastic hinge if both the following requirements are satisfied:

- a) the member has Class 1 cross-sections at the plastic hinge location;
- b) where a transverse force that exceeds 10 % of the shear resistance of the cross section, see 6.2.6, is applied to the web at the plastic hinge location, web stiffeners should be provided within a distance along the member of $h/2$ from the plastic hinge location, $\overline{AC_2}$ where h is the height of the cross section $\overline{AC_2}$.

(3) Where the cross-section of the member $\overline{AC_2}$ vary along its length $\overline{AC_2}$, the following additional criteria should be satisfied:

- a) Adjacent to plastic hinge locations, the thickness of the web should not be reduced for a distance each way along the member from the plastic hinge location of at least $2d$, where d is the clear depth of the web at the plastic hinge location.
- b) Adjacent to plastic hinge locations, the compression flange should be Class 1 for a distance each way along the member from the plastic hinge location of not less than the greater of:
 - $2d$, where d is as defined in (3)a)
 - the distance to the adjacent point at which the moment in the member has fallen to 0,8 times the plastic moment resistance at the point concerned.
- c) Elsewhere in the member the compression flange should be class 1 or class 2 and the web should be class 1, class 2 or class 3.

(4) Adjacent to plastic hinge locations, any fastener holes in tension should satisfy 6.2.5(4) for a distance such as defined in (3)b) each way along the member from the plastic hinge location.

(5) For plastic design of a frame, regarding cross section requirements, the capacity of plastic redistribution of moments may be assumed sufficient if the requirements in (2) to (4) are satisfied for all members where plastic hinges exist, may occur or have occurred under design loads.

(6) In cases where methods of plastic global analysis are used which consider the real stress and strain behaviour along the member including the combined effect of local, member and global buckling the requirements (2) to (5) need not be applied.

Table 5.2 (sheet 1 of 3): Maximum width-to-thickness ratios for compression parts

Internal compression parts						
Class	Part subject to bending	Part subject to compression	Part subject to bending and compression			
Stress distribution in parts (compression positive)						
1	$c/t \leq 72\varepsilon$	$c/t \leq 33\varepsilon$	when $\alpha > 0,5$: $c/t \leq \frac{396\varepsilon}{13\alpha - 1}$ when $\alpha \leq 0,5$: $c/t \leq \frac{36\varepsilon}{\alpha}$			
2	$c/t \leq 83\varepsilon$	$c/t \leq 38\varepsilon$	when $\alpha > 0,5$: $c/t \leq \frac{456\varepsilon}{13\alpha - 1}$ when $\alpha \leq 0,5$: $c/t \leq \frac{41,5\varepsilon}{\alpha}$			
Stress distribution in parts (compression positive)						
3	$c/t \leq 124\varepsilon$	$c/t \leq 42\varepsilon$	when $\psi > -1$: $c/t \leq \frac{42\varepsilon}{0,67 + 0,33\psi}$ when $\psi \leq -1^*)$: $c/t \leq 62\varepsilon(1 - \psi)\sqrt{(-\psi)}$			
$\varepsilon = \sqrt{235/f_y}$	f_y	235	275	355	420	460
	ε	1,00	0,92	0,81	0,75	0,71

*) $\psi \leq -1$ applies where either the compression stress $\sigma \leq f_y$ or the tensile strain $\varepsilon_y > f_y/E$

Table 5.2 (sheet 2 of 3): Maximum width-to-thickness ratios for compression parts

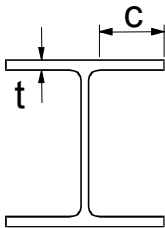
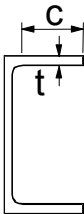
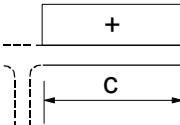
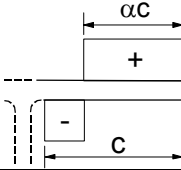
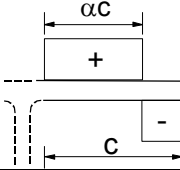
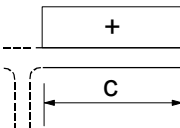
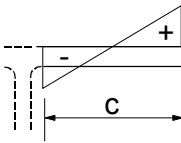
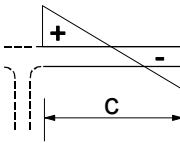
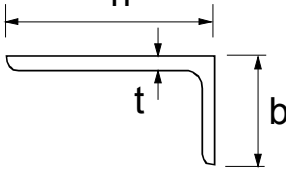
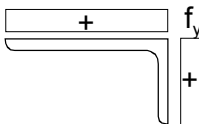
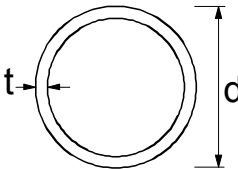
Outstand flanges						
						
Rolled sections			Welded sections			
Class	Part subject to compression	Part subject to bending and compression				
		Tip in compression		Tip in tension		
Stress distribution in parts (compression positive)						
1	$c/t \leq 9\varepsilon$	$c/t \leq \frac{9\varepsilon}{\alpha}$		$c/t \leq \frac{9\varepsilon}{\alpha\sqrt{\alpha}}$		
2	$c/t \leq 10\varepsilon$	$c/t \leq \frac{10\varepsilon}{\alpha}$		$c/t \leq \frac{10\varepsilon}{\alpha\sqrt{\alpha}}$		
Stress distribution in parts (compression positive)						
3	$c/t \leq 14\varepsilon$	$c/t \leq 21\varepsilon\sqrt{k_\sigma}$ For k_σ see EN 1993-1-5				
$\varepsilon = \sqrt{235/f_y}$	f_y	235	275	355	420	460
	ε	1,00	0,92	0,81	0,75	0,71

Table 5.2 (sheet 3 of 3): Maximum width-to-thickness ratios for compression parts

Refer also to “Outstand flanges” (see sheet 2 of 3)		Angles 		Does not apply to angles in continuous contact with other components		
Class	Section in compression					
Stress distribution across section (compression positive)						
3	$\boxed{AC_2} \quad h / t \leq 15\varepsilon \text{ and } \frac{b + h}{2t} \leq 11,5\varepsilon \quad \boxed{AC_2}$					
Tubular sections 						
Class	Section in bending and/or compression					
1	$d / t \leq 50\varepsilon^2$					
2	$d / t \leq 70\varepsilon^2$					
3	$d / t \leq 90\varepsilon^2$					
NOTE For $d / t > 90\varepsilon^2$ see EN 1993-1-6.						
$\varepsilon = \sqrt{235 / f_y}$	f_y	235	275	355	420	460
	ε	1,00	0,92	0,81	0,75	0,71
	ε^2	1,00	0,85	0,66	0,56	0,51