Benchmark Example No. 14

Classification of Steel Cross-sections

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VERiFiCATiON
DCE-EN14 Classification of Steel Cross-sections

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Front Cover

Arnulfsteg, Munich   Photo: Hans Gössing

Overview	
Design Code Family(s):	EN
Design Code(s):	EN 1993-1-1
Module(s):	AQB
Input file(s):	class_steel.dat

1 Problem Description

The problem consists of a steel I- section, as shown in Fig. 1. The cross-section is classified for bending and compression.

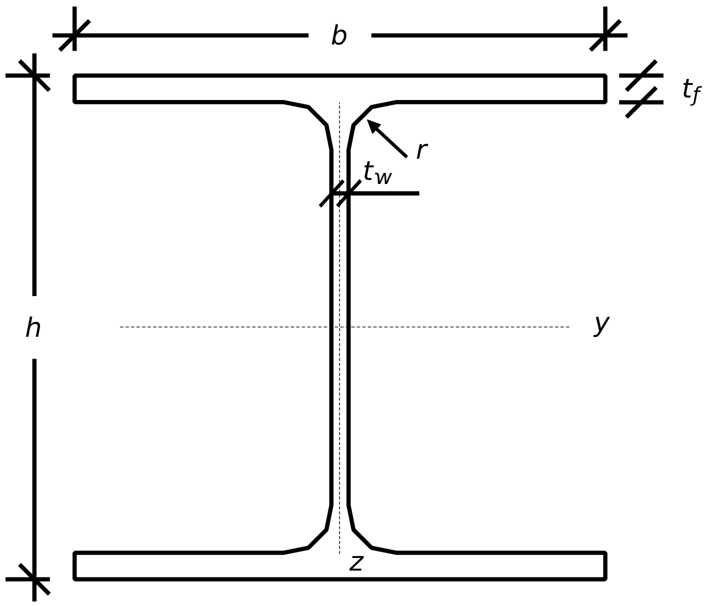

Figure 1: Problem Description

2 Reference Solution

This example is concerned with the classification of steel cross-sections. Section classification is a vital step in checking the suitability of a section to sustain any given design actions. It is concerned with the local buckling susceptibility and is invovled on the resistance checks of the section. The content of this problem is covered by the following parts of EN 1993-1-1:2004 [1]:

- Structural steel (Section 3.2)
- Classification of cross-sections (Section 5.5)
- Cross-section requirements for plastic global analysis (Section 5.6)
- Resistance of cross-sections (Section 6.2)
- Buckling resistance of members (Section 6.3)

A diagrammatic representation of the four classes of section is given in Fig. 2, where a cross-section is subjected to an increasing major axis bending moment until failure [2].

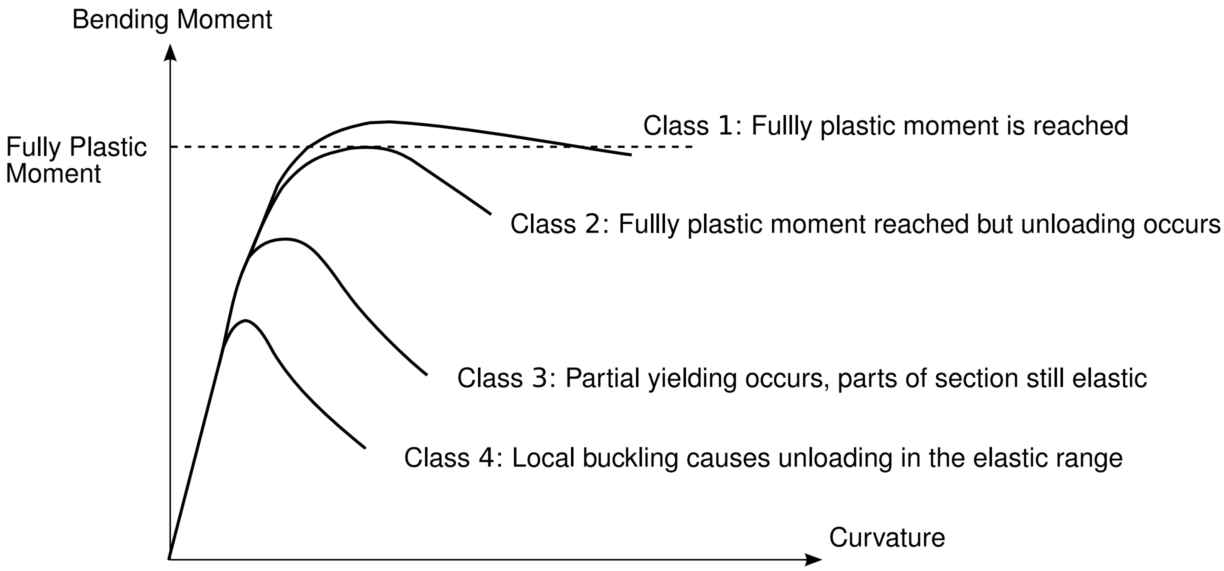

Figure 2: Idealized Moment Curvature Behaviour for Four Classes of Cross-sections

3 Model and Results

The I-section, a UB 457x152x74, with properties as defined in Table 1, is to be classified for bending and compression, with respect to EN 1993-1-1:2005 [1]. For the compression case, an axial load of $N = 3000\ kN$ is applied and for the bending case a moment of $M_y = 500\ kNm$. In **AQB** the classification of the cross-sections is done taking into account the stress levels and the respective design request. Thus, a Class 1 cross-section can be reached, only if a nonlinear design (plastic-plastic) is requested and if the loading is such as to cause the yield stress to be exceeded. Therefore, in order to derive the higher Class possible for this cross-section, we consider these loads, which will cause higher stresses than the yield stress. The calculation steps are presented below and the results are given in Table 2.

Table 1: Model Properties

Material Properties	Geometric Properties	Loading
$S\ 275$	UB 457x152x74	$N = -3000\ kN$
	$b = 154.4\ mm$	$M_y = 500\ kNm$
	$h = 462.0\ mm$	
	$t_f = 17.0\ mm$	
	$t_w = 9.6\ mm$	
	$r = 10.2\ mm$	

Table 2: Results

Case	Part	Result	SOF.	Ref.
	Flange	c/t	3.66	3.66
	Web		42.46	42.46

Table 2: (continued)

Case	Part	Result	SOF.	Ref.
Bending	Flange	Class	1	1
	Web		1	1
Compression	Flange	Class	1	1
	Web		4	4

4 Design Process[1]

Material:

Tab. 3.1 : Nominal values of yield strength f_y and ultimate tensile strength f_u for hot rolled structural steel.

Structural Steel S 275

$f_y = 275\ N/mm^2$ for maximum thickness $\leq 40\ mm$

Tab. 5.2: Maximum width-to-thickness ratios for compression parts

$\epsilon = \sqrt{235/f_y} = 0.924$

Tab. 5.5.1(1): Classification of cross-section basis

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.

• **Bending**:

Tab. 5.2 (sheet 2): Outstand flanges

For the flange: $c = b/2 - t_w/2 - r$

5.5.2 (3): The classification depends on the width to thickness ratio of the parts subject to compression

$c\ /\ t = (154.4/2 - 9.6/2 - 10.2)\ /\ 17 = 3.66$

Tab. 5.2 (sheet 2): Outstand flanges - part subject to compression

$c\ /\ t \leq 9\ \epsilon \leq 8.32$

→ Flange classification: Class 1

Tab. 5.2 (sheet 1): Internal compression parts

For the web: $c = h - 2t_f - 2r$

$c\ /\ t = (462 - 2 \cdot 17 - 2 \cdot 10.2)\ /\ 9.6 = 42.46$

Tab. 5.2 (sheet 1): Internal compression parts - part subject to bending

$c\ /\ t \leq 72\ \epsilon \leq 66.53$

→ Web classification: Class 1

Overall classification for bending: **Class** 1

5.5.2 (1): Classification

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.

• **Compression**:

For the flange as above

→ Flange classification: Class 1

For the web as above : $c\ /\ t = 42.46$

Tab. 5.2 (sheet 1): Internal compression parts - part subject to compression

Class 3: $c\ /\ t \leq 42\ \epsilon \leq 38.8$

Tab. 5.5.2 (8): A part which fails to satisfy the limits of Class 3 should be taken as Class 4

$c\ /\ t = 42.46 > 38.8$

→ Web classification: Class 4

Tab. 5.5.2 (6): A cross-section is classified according to the highest least favourable class

Overall classification for bending: **Class** 4

5.5.2 (1): Classification

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.

[1]The sections mentioned in the margins refer to EN 1993-1-1:2005 [1] unless otherwise specified.

5 Conclusion

This example shows the classification of steel cross-sections for bending and compression. It has been shown that the results are reproduced with excellent accuracy.

6 Literature

[1] *EN 1993-1-1: Eurocode 3: Design of concrete structures, Part 1-1: General rules and rules for buildings*. CEN. 2005.

[2] *Structural Eurocodes - Extracts from the structural Eurocodes for students of structural design*. BSI - British Standards Institution. 2007.