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Benchmark Example No. 14

Classification of Steel Cross-sections

VERiFiCATION
DCE-EN14 Classification of Steel Cross-sections

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The manual and the program have been thoroughly checked for errors. However, SOFiSTiK does not claim that either one is completely error free. Errors and omissions are corrected as soon as they are detected.

The user of the program is solely responsible for the applications. We strongly encourage the user to test the correctness of all calculations at least by random sampling.

Front Cover

6th Street Viaduct, Los Angeles Photo: Tobias Petschke

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.

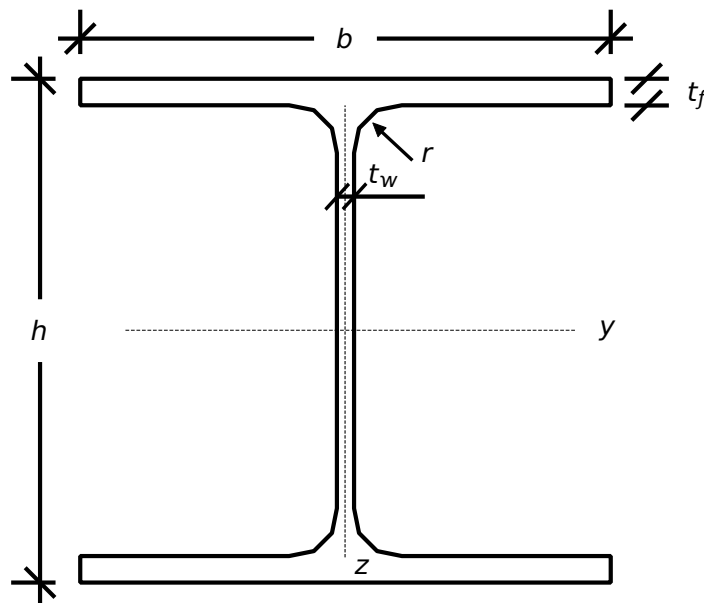


Figure 1: Problem Description

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 involved 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].

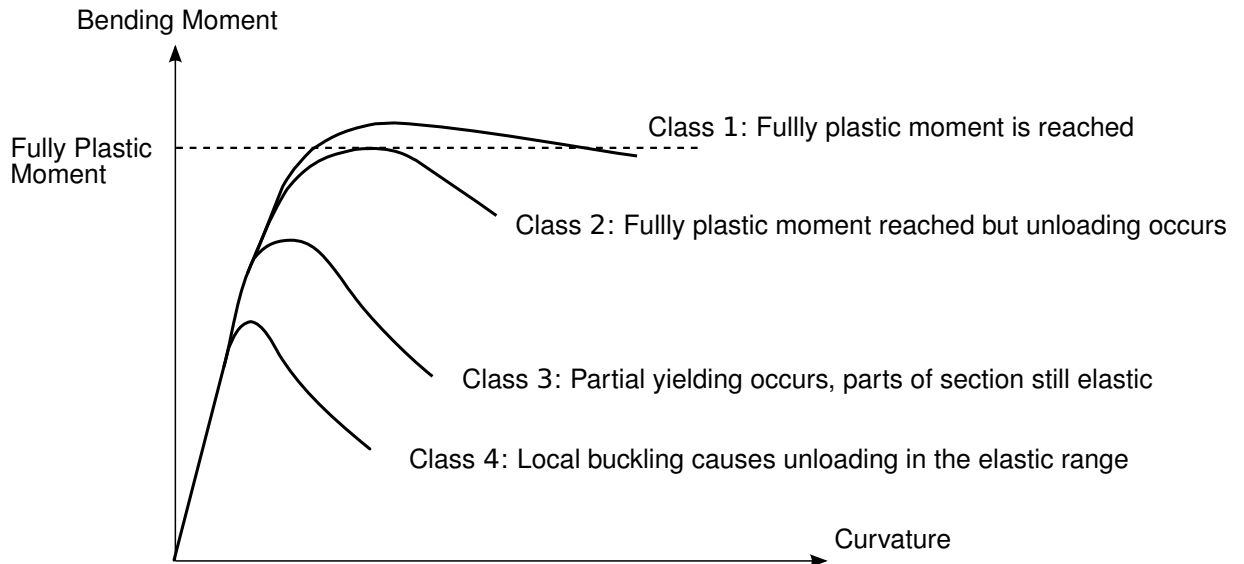


Figure 2: Idealized Moment Curvature Behaviour for Four Classes of Cross-sections

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 $N = 3000 \text{ kN}$ is applied and for the bending case a moment of $M_y = 500 \text{ kNm}$. 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	$N = -3000 \text{ kN}$
	$b = 154.4 \text{ mm}$	$M_y = 500 \text{ kNm}$
	$h = 462.0 \text{ mm}$	
	$t_f = 17.0 \text{ mm}$	
	$t_w = 9.6 \text{ mm}$	
	$r = 10.2 \text{ mm}$	

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 Process¹

Material:

Structural Steel S 275

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

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

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:

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

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

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

→ Flange classification: Class 1

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

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

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

→ Web classification: Class 1

Overall classification for bending: **Class 1**

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 : $c / t = 42.46$

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

$$c / t = 42.46 > 38.8$$

→ Web classification: Class 4

Overall classification for bending: **Class 4**

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.

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

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

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

Tab. 5.2 (sheet 2): Outstand flanges

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

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

Tab. 5.2 (sheet 1): Internal compression parts

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

5.5.2 (1): Classification

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

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

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

5.5.2 (1): Classification

¹The 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 steel 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.
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