Introduction to Local Buckling

(a) Review of members with slender elements

(b) What are the chapters have a relation with Local Buckling

Chapter B Design requirements → B4

Chapter E → section E-7 (Design of Compresion Members)

CM # 14 2010 → Q_s, → Q_A

Limiting values for F_y Grades for slender / non slender members

2010

B.4

CHAPTER B

DESIGN REQUIREMENTS

This chapter addresses general requirements for the analysis and design of steel structures applicable to all chapters of the specification.

The chapter is organized as follows:

B4. MEMBER PROPERTIES

1. Classification of Sections for Local Buckling

For compression, sections are classified as nonslender element or *slender-element sections*. For a nonslender element section, the width-to-thickness ratios of its compression elements shall not exceed λ_r from Table B4.1a. If the width-to-thickness ratio of any compression element exceeds λ_r, the section is a slender-element section.

For flexure, sections are classified as *compact*, *noncompact* or slender-element sections. For a section to qualify as compact, its flanges must be continuously connected to the web or webs and the width-to-thickness ratios of its compression elements shall not exceed the limiting width-to-thickness ratios, λ_p, from Table B4.1b. If the width-to-thickness ratio of one or more compression elements exceeds λ_p, but does not exceed λ_r from Table B4.1b, the section is noncompact. If the width-to-thickness ratio of any compression element exceeds λ_r, the section is a slender-element section.

Classification of Members

slender → or non slender

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→ Slender > λ_r

nonslender < λ_r

B4. MEMBER PROPERTIES

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flexure

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λ → b_f/t_f
↳ h_w/t_w

Flange → unstiffened
web → stiffened

DESIGN OF MEMBERS FOR COMPRESSION

CM #14 #2010

This chapter addresses members subject to axial compression through the centroidal axis.

The chapter is organized as follows:

- E1. General Provisions
- E2. Effective Length
- E3. Flexural Buckling of Members without Slender Elements
- E4. Torsional and Flexural-Torsional Buckling of Members without Slender Elements
- E5. Single Angle Compression Members
- E6. Built-Up Members
- E7. Members with Slender Elements → Section E-7

User Note: For cases not included in this chapter the following sections apply:

- H1 – H2 Members subject to combined axial compression and flexure
- H3 Members subject to axial compression and torsion
- I2 Composite axially loaded members
- J4.4 Compressive strength of connecting elements

E7. MEMBERS WITH SLENDER ELEMENTS

Chapter E

This section applies to slender-element compression members, as defined in Section B4.1 for elements in uniform compression.

The *nominal compressive strength*, P_n, shall be the lowest value based on the applicable *limit states* of *flexural buckling*, *torsional buckling*, and *flexural-torsional buckling*.

$$P_n = F_{cr} A_g \tag{E7-1}$$

spec- 2010
CM # 14

The critical *stress*, F_{cr}, shall be determined as follows:

$\frac{KL}{r} \Rightarrow \frac{L_c}{r}$ was replaced in specs - 2016

Q new Factor

(a) When $\frac{KL}{r} \leq 4.71\sqrt{\frac{E}{QF_y}}$ $\left(\text{or } \frac{QF_y}{F_e} \leq 2.25\right)$

inelastic Column

$$F_{cr} = Q\left[0.658^{\frac{QF_y}{F_e}}\right] F_y \tag{E7-2}$$

(b) When $\frac{KL}{r} > 4.71\sqrt{\frac{E}{QF_y}}$ $\left(\text{or } \frac{QF_y}{F_e} > 2.25\right)$

Elastic Column

$$F_{cr} = 0.877 F_e \tag{E7-3}$$

$$\lambda_c^2 = \frac{F_y}{F_e}$$

$$\lambda_c^2 = 2.25$$

E7-2

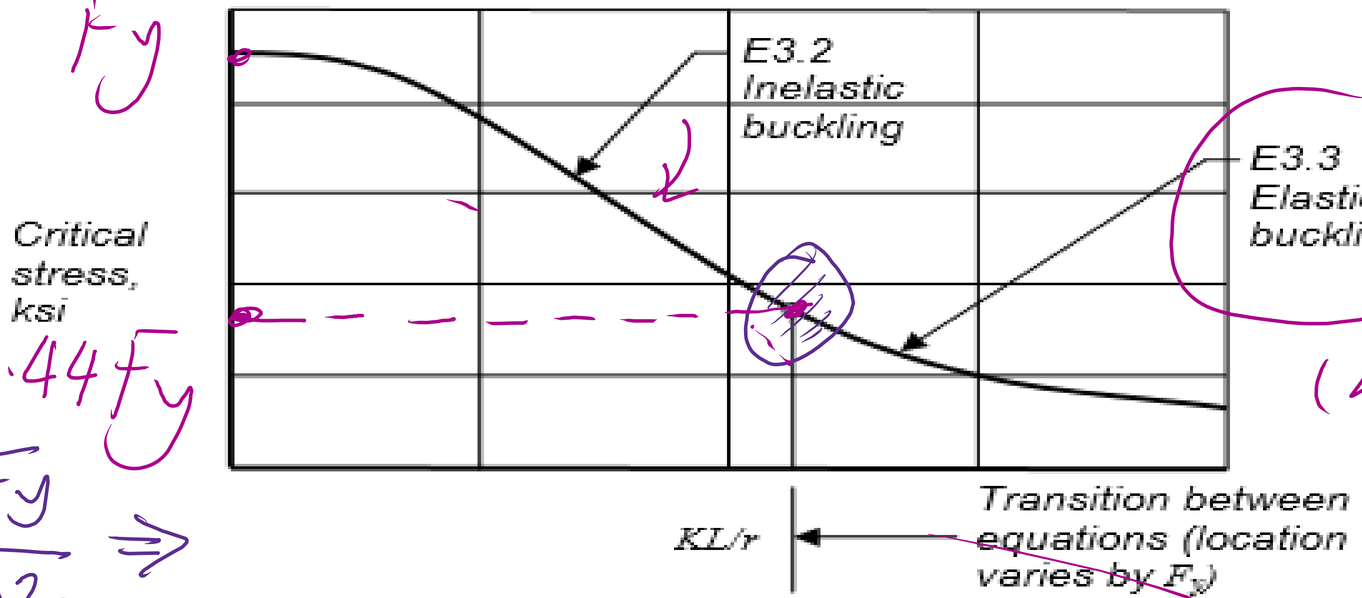


Figure E-1 Standard Column Curve

$$\frac{F_y}{2.25} = 0.44F_y$$

$$F_e = \frac{\pi^2 E}{\left(\frac{KL}{r}\right)^2} = \frac{F_y}{\lambda_c^2} \Rightarrow$$

$$\left(\frac{KL}{r}\right)^2 = \frac{2.25\pi^2 E}{F_y}$$

$$\frac{KL}{r} = 4.71\sqrt{\frac{E}{F_y}}$$

TRANSITION POINT LIMITING VALUES OF KL/r		
F_y ksi (MPa)	Limiting KL/r	$0.44F_y$ ksi (MPa)
36 (248)	134	15.8 (109)
50 (345)	113	22.0 (152)
60 (414)	104	264. (182)
70 (483)	96	30.8 (212)

$$4.71\sqrt{\frac{E}{F_y}} \Rightarrow 4.71\sqrt{\frac{29000}{36}} = 133.68$$

B4 → 1a

Chapter B

→ Flanges

1a. Unstiffened Elements

→ Unstiffened

For *unstiffened elements* supported along only one edge parallel to the direction of the compression *force*, the width shall be taken as follows:

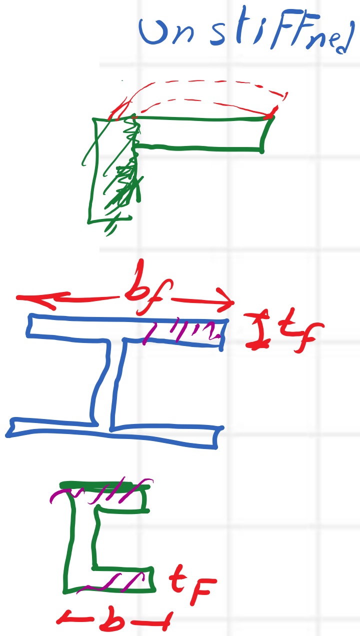
(a) For flanges of I-shaped members and tees, the width, b, is one-half the full-flange width, b_f.

(b) For legs of angles and flanges of channels and zees, the width, b, is the full *nominal dimension*.

(c) For plates, the width, b, is the distance from the free edge to the first row of *fasteners* or line of welds.

(d) For stems of tees, d is taken as the full nominal depth of the section.

what are the unstiffened items



User Note: Refer to Table B4.1 for the graphic representation of unstiffened element dimensions.

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⇒ CM #14 16.1-40/41 Section E

1. Slender Unstiffened Elements, Q_s

The reduction factor, Q_s, for slender *unstiffened elements* is defined as follows:

(a) For flanges, angles and plates projecting from rolled *columns* or other compression members:

Qs Equations

(i) When $\frac{b}{t} \le 0.56\sqrt{\frac{E}{F_y}}$

$$Q_s = 1.0 \tag{E7-4}$$

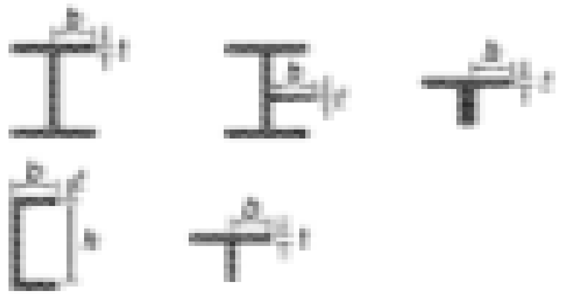
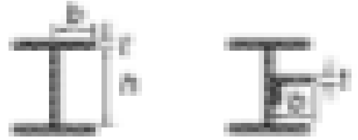
(ii) When $0.56\sqrt{\frac{E}{F_y}} < \frac{b}{t} < 1.03\sqrt{\frac{E}{F_y}}$

$$Q_s = 1.415 - 0.74\left(\frac{b}{t}\right)\sqrt{\frac{F_y}{E}} \tag{E7-5}$$

(iii) When $\frac{b}{t} \ge 1.03\sqrt{\frac{E}{F_y}}$

$$Q_s = \frac{0.69E}{F_y\left(\frac{b}{t}\right)^2} \tag{E7-6}$$

TABLE B4.1a
Width-to-Thickness Ratios: Compression Elements Members Subject to Axial Compression

	Case	Description of Element	Width-to-Thickness Ratio	Limiting Width-to-Thickness Ratio λ_r (nonslender/slender)	Examples
Unstiffened Elements	1	Flanges of rolled I-shaped sections, plates projecting from rolled I-shaped sections; outstanding legs of pairs of angles connected with continuous contact, flanges of channels, and flanges of tees	b/t	$0.56\sqrt{\frac{E}{F_y}}$	
	2	Flanges of built-up I-shaped sections and plates or angle legs projecting from built-up I-shaped sections	b/t	$0.64\sqrt{\frac{k_c E}{F_y}}$ [a]	
	3	Legs of single angles, legs of double angles with separators, and all other unstiffened elements	b/t	$0.45\sqrt{\frac{E}{F_y}}$	
	4	Stems of tees	d/t	$0.75\sqrt{\frac{E}{F_y}}$	

axial Compresion

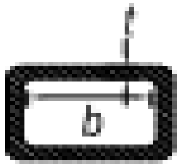
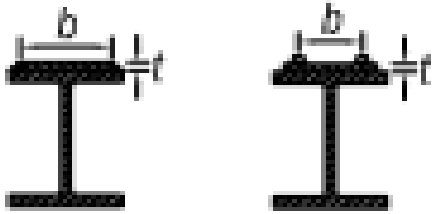
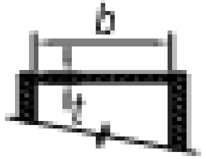
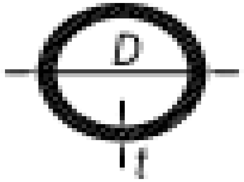
Flanges of W → $0.56\sqrt{\frac{E}{F_y}}$

Built up → $0.64\sqrt{k_c\frac{E}{F_y}}$

Legs → $0.45\sqrt{\frac{E}{F_y}}$

T → $0.75\sqrt{\frac{E}{F_y}}$

B 4.1a Stiffened Elements CM # 14 # 2010

Stiffened Elements	5	Webs of doubly-symmetric I-shaped sections and channels	h/t_w	$1.49\sqrt{\frac{E}{F_y}}$		h/t_w
	6	Walls of rectangular HSS and boxes of uniform thickness	b/t	$1.40\sqrt{\frac{E}{F_y}}$		b/t
	7	Flange cover plates and diaphragm plates between lines of fasteners or welds	b/t	$1.40\sqrt{\frac{E}{F_y}}$		b/t
	8	All other stiffened elements	b/t	$1.49\sqrt{\frac{E}{F_y}}$		b/t
	9	Round HSS	D/t	$0.11\frac{E}{F_y}$		D/t

Sec B-3

1b. Stiffened Elements

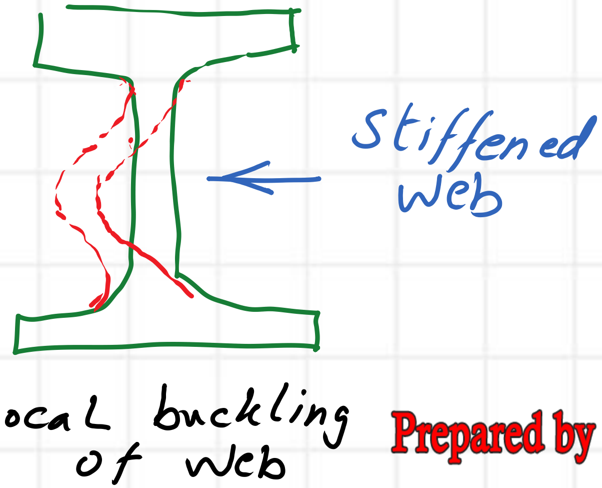
For *stiffened elements* supported along two edges parallel to the direction of the compression *force*, the width shall be taken as follows:

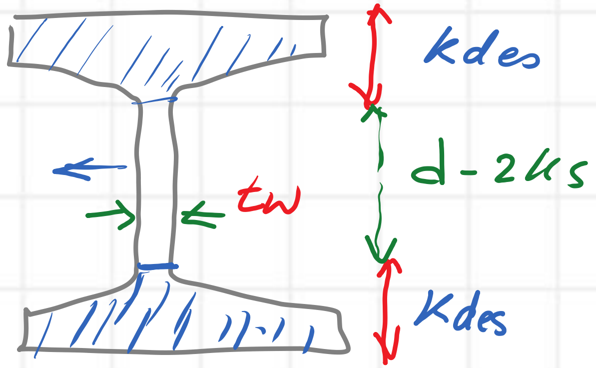
(a) For webs of rolled or *formed sections*, h is the clear distance between flanges less the fillet or corner radius at each flange; h_c is twice the distance from the center of gravity to the inside face of the compression flange less the fillet or corner radius.

$$\lambda = \frac{d - 2k_s}{t_w}$$

$$\lambda_r = 1.49\sqrt{\frac{F_y}{E}}$$

Item -5 stiffened





From tables 1-1 →

Prepared by Eng.Maged Kamel.

Qa 16.1 → 43

2. Slender Stiffened Elements, Q_a

The reduction factor, Q_a , for slender *stiffened elements* is defined as follows:

$$Q_a = \frac{A_e}{A_g} \quad \text{(E7-16)}$$

where

A_g = gross cross-sectional area of member, in.^{2} (mm^2)

A_e = summation of the effective areas of the cross section based on the reduced *effective width*, b_e, in.^{2} (mm^2)

The reduced effective width, b_e, is determined as follows:

(a) For uniformly compressed slender elements, with $\frac{b}{t} \geq 1.49\sqrt{\frac{E}{f}}$, except flanges of square and rectangular sections of uniform thickness:

$$b_e = 1.92t\sqrt{\frac{E}{f}}\left[1 - \frac{0.34}{(b/t)}\sqrt{\frac{E}{f}}\right] \leq b \quad \text{(E7-17)}$$

where

f is taken as F_{cr} with F_{cr} calculated based on $Q = 1.0$

(b) For flanges of square and rectangular *slender-element sections* of uniform thickness with $\frac{b}{t} \geq 1.40\sqrt{\frac{E}{f}}$:

$$b_e = 1.92t\sqrt{\frac{E}{f}}\left[1 - \frac{0.38}{(b/t)}\sqrt{\frac{E}{f}}\right] \leq b \quad \text{(E7-18)}$$

where

$f = P_n/A_e$

User Note: In lieu of calculating $f = P_n/A_e$, which requires iteration, f may be taken equal to F_y. This will result in a slightly conservative estimate of *column available strength*.