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1 The terms  $E$  &  $E_T$   
Young Modulus of Elasticity & Tangent modulus  
of Elasticity → From Prof. SEGUi

2 Effective Length ( $KL$ ) - Cases of End Connections  
For Columns

3 AISC Provision For Compression members

4 Solved Problems 4.2 Prof. SEGUi's book

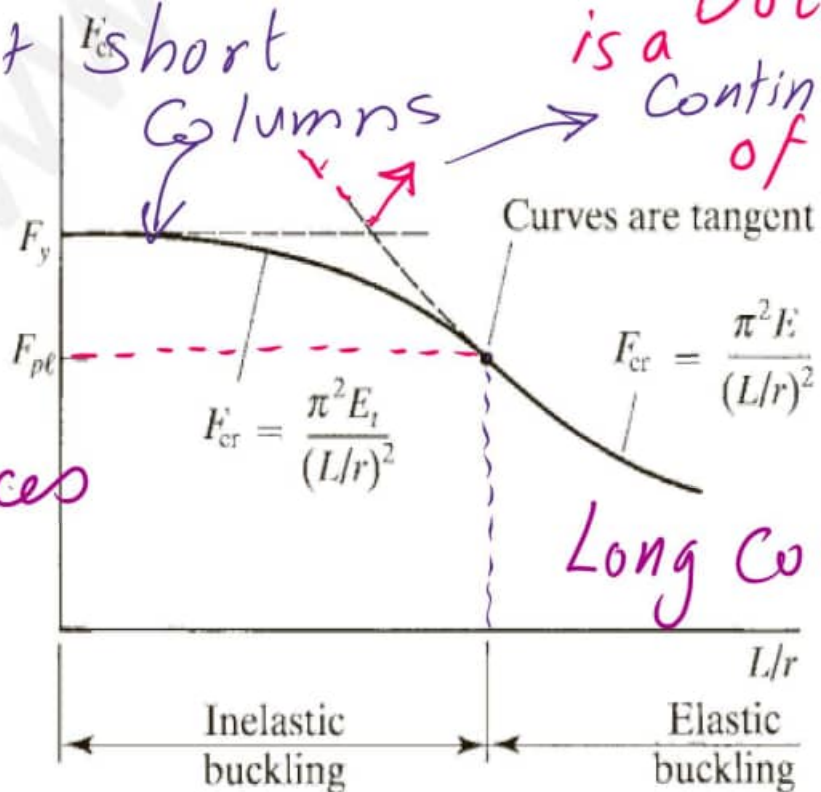


This difficulty was initially resolved by Friedrich Engesser, who proposed in 1889 the use of a variable tangent modulus,  $E_t$ , in Equation 4.3. For a material with a stress-strain curve like the one shown in Figure 4.5,  $E$  is not a constant for stresses greater than the proportional limit  $F_{pl}$ . The tangent modulus  $E_t$  is defined as the slope of the tangent to the stress-strain curve for values of  $f$  between  $F_{pl}$  and  $F_y$ . If the compressive stress at buckling,  $P_{cr}/A$ , is in this region, it can be shown that

$$P_{cr} = \frac{\pi^2 E_t I}{L^2} \quad (4.5)$$

Prof. SEGUI

FIGURE 4.6  
represent

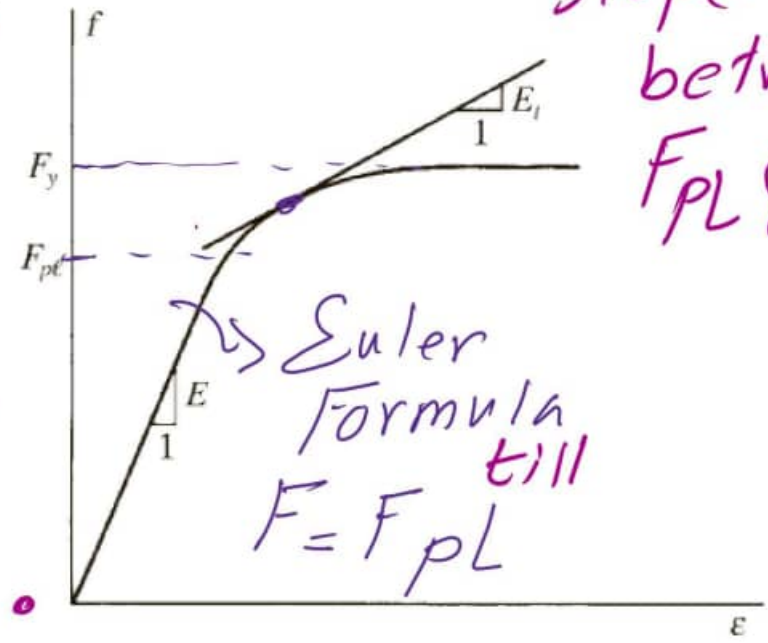


is a Dotted Line continuation of Euler Formula

$E_t$  replaces  $E$

Long Columns

4.5



slope between  $F_{pl}$  &  $F_y$

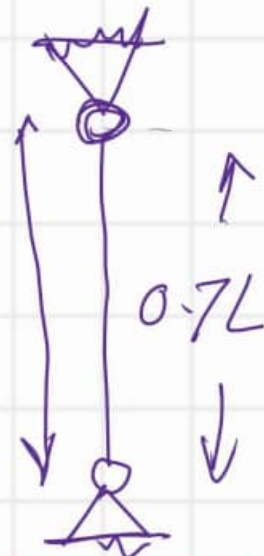
Euler Formula till  $F = F_{pl}$

# Effective Length $kL$



$k=1$

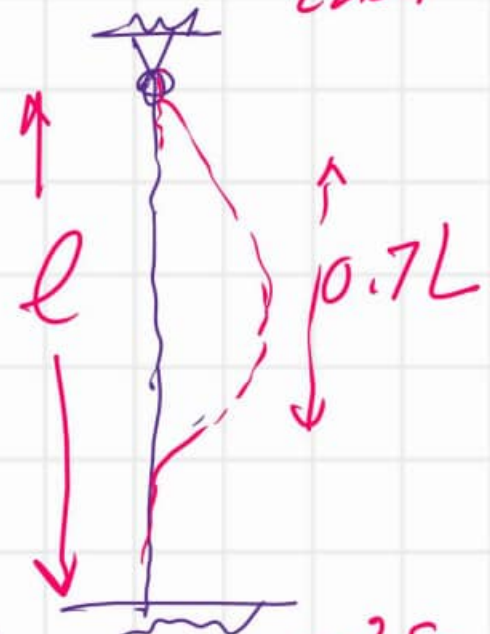
$\Rightarrow$



Reducing Column height will increase  $F_{Cr}$

$\Rightarrow$

it is found that



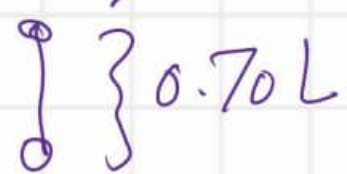
$$F_{Cr} = \frac{\pi^2 E}{(0.7L)^2}$$

$k=0.70$

$$F_{Cr} = 2.04 \frac{\pi^2 E}{L^2}$$

same

Then it is Equivalent to



For a Column with Length  $L$  (Height)

$$F_{Cr} = \frac{\pi^2 E}{(kL)^2}$$

$k=1$

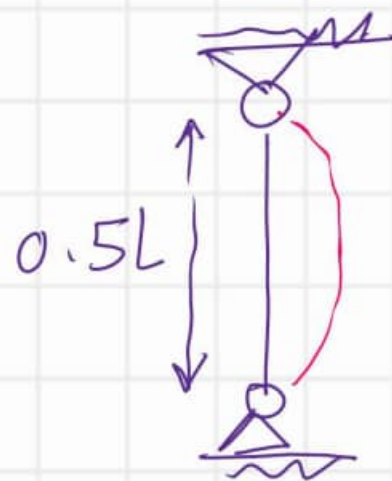
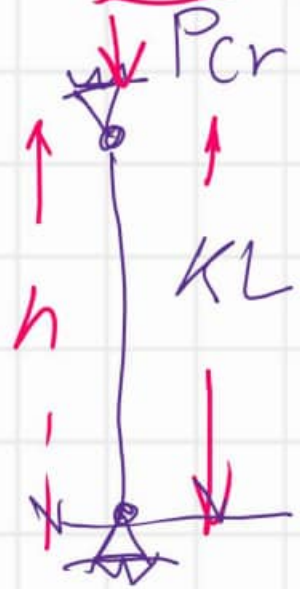
if the same Column has

$$h = 0.70 L$$

then

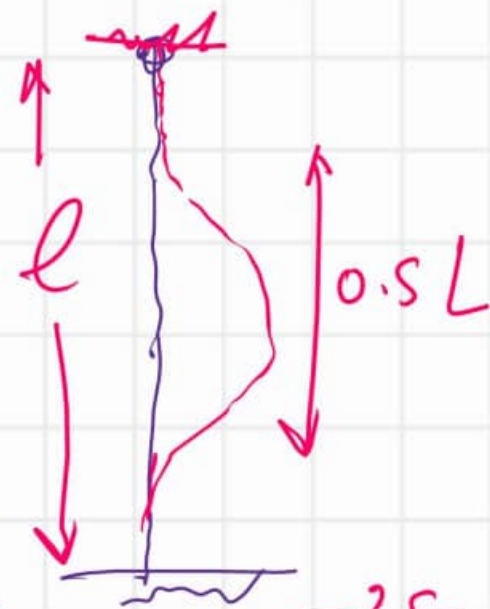
$$F_{Cr} = \frac{\pi^2 E}{(0.7L)^2} = 2.05 \frac{\pi^2 E}{(L)^2}$$

# Effective Length $kL$



Reducing Column height will increase  $F_{cr}$

$\Rightarrow$



it is found that

$$F_{cr} = \frac{\pi^2 E}{(0.5L)^2}$$

$$k = 0.5$$

$$F_{cr} = (4) \frac{\pi^2 E}{L^2}$$

same

Then it is Equivalent to  $0.70L$

For a Column with Length  $L$  (Height)

$$F_{cr} = \frac{\pi^2 E}{(kL)^2}$$

$$k = 1$$

if the same Column has

$h = 0$   
then

$$F_{cr} = \frac{\pi^2 E}{(0.5L)^2} = (4) \frac{\pi^2 E}{(L)^2}$$

$k = 0.5$



AISC-360-16

16.1-33

AISC-360-10  $\Rightarrow$  16.1-31

## CHAPTER E

# DESIGN OF MEMBERS FOR COMPRESSION

This chapter addresses members subject to axial compression.

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 Single Angles and Members without Slender Elements
- E5. Single-Angle Compression Members
- E6. Built-Up Members
- E7. Members with Slender Elements

## GENERAL PROVISIONS

The *design compressive strength*,  $\phi_c P_n$ , and the *allowable compressive strength*,  $P_n / \Omega_c$ , are determined as follows.

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

$$\phi_c = 0.90 \text{ (LRFD)} \quad \Omega_c = 1.67 \text{ (ASD)}$$

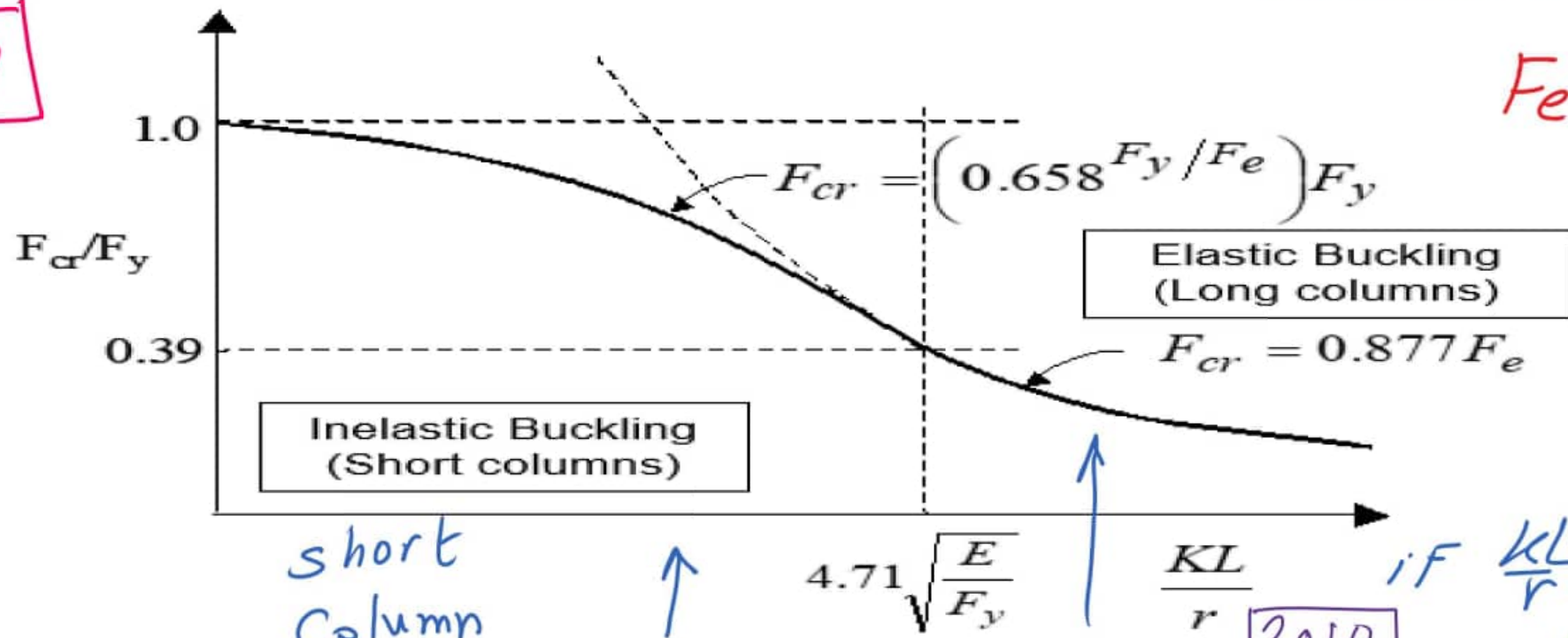
AISC E-1  $\Rightarrow$  AISC-360  
10 & 16

$$F_{cr} = 0.877 F_e \quad \Downarrow$$

Global buckling

$$F_e = \frac{P_e}{A_g} = \frac{\pi^2 E}{\left(\frac{KL}{r}\right)^2}_{\min.}$$

2010



short  
column

↑  
if less

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2010

if  $\frac{KL}{r} > 4.71 \sqrt{\frac{E}{F_y}}$

Long Column

**E2. EFFECTIVE LENGTH**

AISC-360-2010

KL Expression

The *effective length factor*,  $K$ , for calculation of member slenderness,  $KL/r$ , shall be determined in accordance with Chapter C or Appendix 7,

where

$L$  = laterally unbraced length of the member, in. (mm)

$r$  = radius of gyration, in. (mm)

 $KL/r \not> 200$ 

**User Note:** For members designed on the basis of compression, the effective slenderness ratio  $KL/r$  preferably should not exceed 200.

**E2. EFFECTIVE LENGTH**

AISC-360-16

16.1-33

The effective length,  $L_c$ , for calculation of member slenderness,  $L_c/r$ , shall be determined in accordance with Chapter C or Appendix 7,

where

$K$  = effective length factor

$L_c = KL$  = effective length of member, in. (mm)

$L$  = laterally unbraced length of the member, in. (mm)

$r$  = radius of gyration, in. (mm)

 $L_c = KL$ 

**User Note:** For members designed on the basis of compression, the effective slenderness ratio,  $L_c/r$ , preferably should not exceed 200.

 $L_c/r \not> 200$ 

**User Note:** The effective length,  $L_c$ , can be determined through methods other than those using the effective length factor,  $K$ .

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2010

### E3. FLEXURAL BUCKLING OF MEMBERS WITHOUT SLENDER ELEMENTS

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

**User Note:** When the torsional *unbraced length* is larger than the lateral unbraced length, Section E4 may control the design of wide flange and similarly shaped columns.

The *nominal compressive strength*,  $P_n$ , shall be determined based on the *limit state of flexural buckling*.

$$P_n = F_{cr} A_g \quad (\text{E3-1})$$

The *critical stress*,  $F_{cr}$ , is determined as follows:

$$(a) \text{ When } \frac{KL}{r} \leq 4.71 \sqrt{\frac{E}{F_y}} \quad (\text{or } \frac{F_y}{F_e} \leq 2.25)$$

$$F_{cr} = \left[ 0.658 \frac{F_y}{F_e} \right] F_y \quad (\text{E3-2})$$

$$(b) \text{ When } \frac{KL}{r} > 4.71 \sqrt{\frac{E}{F_y}} \quad (\text{or } \frac{F_y}{F_e} > 2.25)$$

$$F_{cr} = 0.877 F_e \quad (\text{E3-3})$$

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### E3. FLEXURAL BUCKLING OF MEMBERS WITHOUT SLENDER ELEMENTS

2016

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

**User Note:** When the torsional effective length is larger than the lateral effective length, Section E4 may control the design of wide-flange and similarly shaped columns.

The nominal compressive strength,  $P_n$ , shall be determined based on the limit state of flexural buckling:

$$P_n = F_{cr} A_g \quad (\text{E3-1})$$

The critical stress,  $F_{cr}$ , is determined as follows:

(a) When  $\frac{L_c}{r} \leq 4.71 \sqrt{\frac{E}{F_y}}$  (or  $\frac{F_y}{F_e} \leq 2.25$ )

$$F_{cr} = \left( 0.658^{\frac{F_y}{F_e}} \right) F_y \quad (\text{E3-2})$$

*L<sub>c</sub> instead of KL*

(b) When  $\frac{L_c}{r} > 4.71 \sqrt{\frac{E}{F_y}}$  (or  $\frac{F_y}{F_e} > 2.25$ )

$$F_{cr} = 0.877 F_e \quad (\text{E3-3})$$

16.1-33

AISC-360-2010

CM # 14

where

$F_e$  = elastic *buckling* stress determined according to Equation E3-4, as specified in Appendix 7, Section 7.2.3(b), or through an elastic buckling analysis, as applicable, ksi (MPa)

$$F_e = \frac{\pi^2 E}{\left(\frac{KL}{r}\right)^2} \quad (\text{E3-4})$$

16.1-36

FLEXURAL BUCKLING OF MEMBERS WITHOUT SLENDER ELEMENTS

[Sect. E3.

AISC-360-16

CM # 15

$F_e$  = elastic buckling stress determined according to Equation E3-4, as specified in Appendix 7, Section 7.2.3(b), or through an elastic buckling analysis, as applicable, ksi (MPa)

$$= \frac{\pi^2 E}{\left(\frac{L_c}{r}\right)^2} \quad (\text{E3-4})$$

$\leftarrow L_c = KL$

$F_y$  = specified minimum yield stress of the type of steel being used, ksi (MPa)

$r$  = radius of gyration, in. (mm)

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