SEGUI

Metric Version

7th Edition

Practice Problem 5-6-1 For non Compact steel beam section

(a) Conversion Factor From ksi → N/mm^2

(b) Metric Equivalent Section for W 12X65

(C) Find M_n For the non-Compact Section

From LFB ⇒ $\phi_b M_n$

(D) Find D & L → $\underbrace{1.2D + 1.6L}_{M_{ult}} \leq \phi_b M_n$ LRFD

(E) Find D & L ⇒ $\underbrace{D+L}_{M_T} \leq \frac{M_n}{\Omega_b}$ ASD

Brief content of post 41M

Prepared by Eng.Maged Kamel.

Find conversion factor from KSI to MPA

$1\ Lb = 4.448\ N$

$1\ inch^2 = (25.40)^2\ mm^2$

F_y stresses

F_{ult}

$\rightarrow Ksi \rightarrow N/mm^2$

$E = 29(10^3) \rightarrow \approx 2(10^5)$ MPA

$$1\ Psi = \frac{4.448}{(25.40)^2} = 6.895(10^{-3})\ \frac{N}{mm^2}$$

$$1\ ksi = 10^3(6.895)(10^{-3}) = 6.895\ \frac{N}{mm^2}$$

A36 $\Rightarrow F_y = 36$ ksi $\Rightarrow 36(6.895) = 248.22 \approx 250\ \frac{N}{mm^2}$

A572 $\Rightarrow F_y = 50$ ksi $\Rightarrow 50(6.895) = 344.75 = 345\ \frac{N}{mm^2}$

A992 $\Rightarrow F_y = 50$ Ksi $\Rightarrow$

A529 $\Rightarrow = 55$ ksi $\Rightarrow 379.22\ \frac{N}{mm^2} = 380\ N/mm^2$

A913 $F_U = 70 \Rightarrow 482.65 \Rightarrow 485\ N/mm^2$

80 ksi $\Rightarrow 552 \Rightarrow 550\ \frac{N}{mm^2}$

1" = 25.40 ⇒ 1" ≃ 254 mm = 305 mm → W310 × 97 kg/m

W12 × 65

Specification

$\frac{1\,Lb}{1\,Ft}$ $(1.488)\left(\frac{kg}{Lb}\right)\left(\frac{Ft}{m}\right)(65) = 96.72$ → 97 kg/m

Table 17-1
SI Equivalents of Standard U.S. Shape Profiles
W-Shapes

W12 X65

Shape in. × lb/ft	SI Equivalent mm × kg/m
[illegible]×230	[illegible]×342
×210	×313
×190	×283
×170	×253
×152	×226
×136	×202
×120	×179
×106	×158
×96	×143
×87	×129
×79	×117
×72	×107
12 ×65	310 ×97
W12×58	W310×86

Shape in. × lb/ft	SI Equivalent mm × kg/m
[illegible]	[illegible]
W10×112	W250×167
×100	×149
×88	×131
×77	×115
×68	×101
×60	×89
×54	×80
×49	×73
W10×45	W250×67
×39	×58
×33	×49.1
W10×30	W250×44.8
×26	×38.5

Shape in. × lb/ft	SI Equivalent mm × kg/m
[illegible]×331	[illegible]×522
×31	×46.1
W8×28	W200×41.7
×24	×35.9
W8×21	W200×31.3
×18	×26.6
W8×15	W200×22.5
×13	×19.3
×10	×15.0
W6×25	W150×37.1
×20	×29.8
×15	×22.5

SEGUi _ 7ths Edition

Practice problem 5-6-1

Bending Strength of Noncompact Shapes

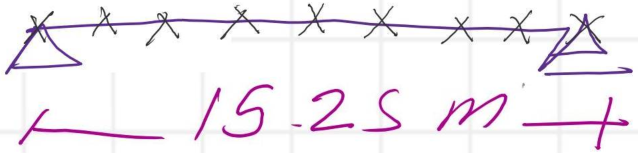
5.6-1 A W12 × 65 (W310 × 97) is used as a simply supported, uniformly loaded beam with a span length of 50 feet (15,250 mm) and continuous lateral support. The yield stress, F_y, is 50 ksi (345 MPa). If the ratio of live load to dead load is 3, compute the available strength and determine the maximum total service load, in kips/ft (kN/m), that can be supported.

a. Use LRFD.

b. Use ASD.

Metric

Practice problem-5-6-1M



Conversions

$L = 50' = 50(0.3048)$

$= 15.24\ m \Rightarrow 15.25\ m$

Solution

$F_y = 50\ ksi = 345\ \frac{N}{mm^2} = 345\ MPA$

$\frac{L}{D} = 3$

Continuous Lateral support

Check $\frac{b_f}{2t_f}$, $\frac{h}{t_w}$ ratios For Local buckling Parameter

L.B.

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is section non compact?

Table 1-1 f symbol Shapes Exceeds Compact Limit

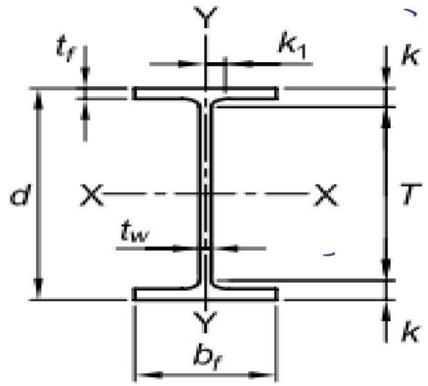

Table 1-1 (continued)
W-Shapes
Dimensions

There is f symbol

f
W12 X 65

Shape	Area, A	Depth, d	Web Thickness, t_w	Web $\frac{t_w}{2}$	Flange Width, b_f	Flange Thickness, t_f	Distance k, k_{des}	Distance k, k_{det}	Distance k_1	Distance T	Distance Workable Gage
	in.^{2}	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.
W12 x65^f	19.1	12.1 12 1/8	0.390 3/8	3/16	12.0 12	0.605 5/8	1.20	1 1/2	1	↓	↓

$F_y = 50$ ksi

[c] Shape is slender for compression with $F_y = 50$ ksi.
[f] Shape exceeds compact limit for flexure with $F_y = 50$ ksi.
[g] The actual size, combination and orientation of fastener components should be compared with the geometry of the cross section to ensure compatibility.
[h] Flange thickness greater than 2 in. Special requirements may apply per AISC *Specification* Section A3.1c.
[v] Shape does not meet the h/t_w limit for shear in AISC *Specification* Section G2.1(a) with $F_y = 50$ ksi.

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Data for W310x97

Use Excel sheet for V16 from AISC

W12X65 $\Rightarrow$ W310X97

Type	Manual	T_F	AISC_Manual_La	W-Kg/m	A-mm2	d-mm	d_{det}	Ht	h	OD	b_f	b_{fdet}	B	b	ID	t_w
W	W12X65	F	W310X97	97.0	12300	307	308	-	-	-	305	305	-	-	-	9.91

$b_f = 305$ mm

Area $A_g = 12300$ mm^2

$t_f = 15.40$ mm

$I_x = 222(10)^6$ mm^4 $\quad r_x = 134$ mm

$I_y = 72.40(10)^6$ mm^4 $\quad r_y = 76.70$ mm

$t_w = 9.91$ mm

$d = 307$ mm

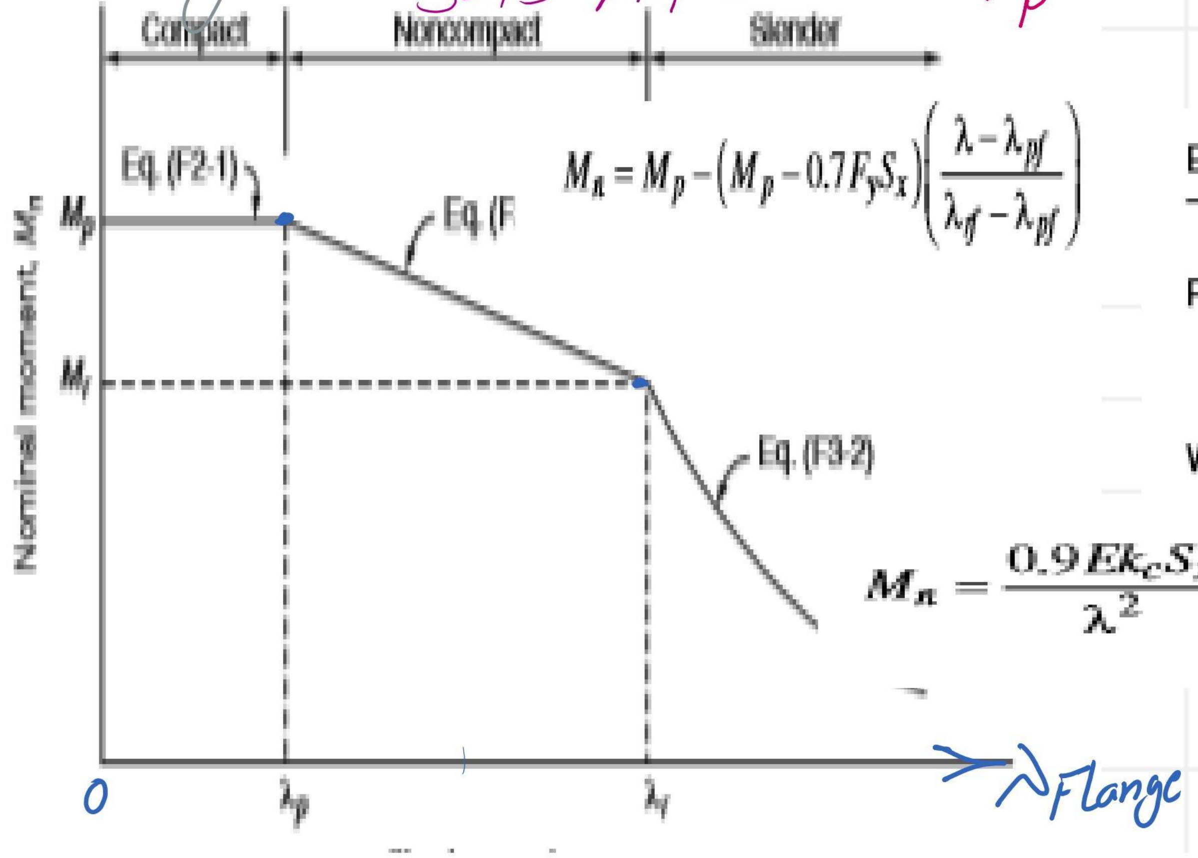
I_x-10^6 mm4	Z_x-10^3 mm3	S_x-10^3 mm3	r_x	I_y-10^6 mm3	Z_y-10^3 mm3	S_y-10^3 mm3	r_y-mm
222	1590	1440	134	72.4	723	477	76.7

$Z_x = 1590(10)^3$ mm^3 $\quad S_x = 1440(10)^3$ mm^3

$F_y = 50\ ksi$

$345\ MPa$

$\lambda_p = 0.38\sqrt{\frac{E}{F_y}} = 0.38\left(\frac{2(10^5)}{345}\right)^{1/2} = 9.15$



$$M_n = M_p - (M_p - 0.7F_yS_x)\left(\frac{\lambda - \lambda_{pf}}{\lambda_{rf} - \lambda_{pf}}\right)$$

$$M_n = \frac{0.9Ek_cS_x}{\lambda^2}$$

$\lambda_r = 1\sqrt{\frac{E}{F_y}}$ $= 24.077$

Element	λ	λ_p	λ_r	
Flange	$\frac{b_f}{2t_f}$	$0.38\sqrt{\frac{E}{F_y}}$	$1.0\sqrt{\frac{E}{F_y}}$	item No. 10
Web	$\frac{h}{t_w}$	$3.76\sqrt{\frac{E}{F_y}}$	$5.70\sqrt{\frac{E}{F_y}}$	item No. 15

$\lambda_{pw} = 3.76\sqrt{\frac{2(10^5)}{345}} = 90.53$

$\lambda_{r_w} = 5.7\sqrt{\frac{2(10)^5}{345}}$

137.24

where

$k_c = \frac{4}{\sqrt{h/t_w}}$ and shall not be taken less than 0.35 nor greater than 0.76 for calculation purposes

h = distance as defined in Section B4.1b, in. (mm)

$\lambda = \frac{b_f}{2t_f}$

b_f = width of the flange, in. (mm)

t_f = thickness of the flange, in. (mm)

$\lambda_{pf} = \lambda_p$ is the limiting slenderness for a compact flange, defined in Table B4.1b

$\lambda_{rf} = \lambda_r$ is the limiting slenderness for a noncompact flange, defined in Table B4.1b

find lamda values for flange and web

Estimate λ_p, λ_r Flange & Web

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$$\frac{b_f}{2t_f} = 9.92 \begin{cases} \lambda_p = 9.15 \\ \lambda_r = 24.077 \end{cases}$$

$$\frac{h}{t_w} = 24.90 \begin{cases} \lambda_{pw} = 90.53 \\ \lambda_{rw} = 137.24 \end{cases}$$

From Table

$b_f/2t_f$	b/t	b/t_{des}	h/t_w
9.92	–	–	24.9

W 310X97

Compare $\frac{b_f}{2t_f}$ with λ_p, λ_r For flange

Compare $\frac{h}{t_w}$ with λ_p, λ_r For Web

Why W section is non-compact?

$Z_x = 1590(10^3)\ mm^3$ $S_x = 1440(10)^3\ mm^3$

$\lambda_{pF} = 9.15$

$\lambda_{rF} = 24.07$

W310X97

$\lambda_{pw} = 90.53$

$\lambda_{rw} = 137.243$ } $F_y = 345$ MPa

Section properties

W12X65

$b_f/2t_f = 9.92 > \lambda_{pF}\ 9.15$

$< \lambda_{rF}\ 24.07$

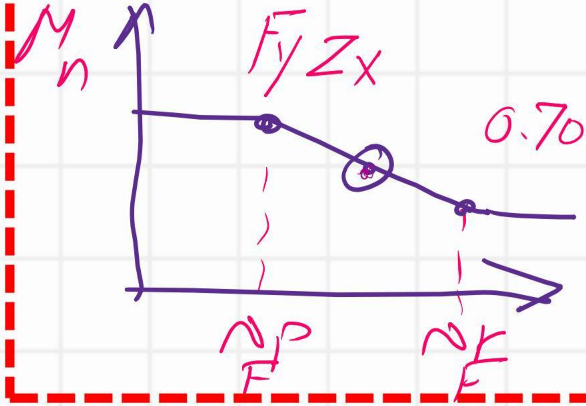
Find Mn and 0.7*Fy* Sx

Section is non-Compact due to Flange

While $\frac{h}{t_w} = 24.90 < \lambda_{pw}$ (90.53)

Estimate $F_y Z_x = 345(1590)\frac{(10^3)}{10^6}$ MPa$(mm^3) = 548.55(10^6)$ N.mm

$0.70 F_y S_x = 0.7(345)\frac{1440(10)^3}{10^6} = 347.76(10^6)$ N.mm



$$\boxed{\begin{aligned} F_y Z_x &= 548.55(10)^6\ N.mm \\ 0.70 F_y S_x &= 347.76(10)^6\ N.mm \end{aligned}}$$

= 548.55 KN.m

= 347.76 KN.m

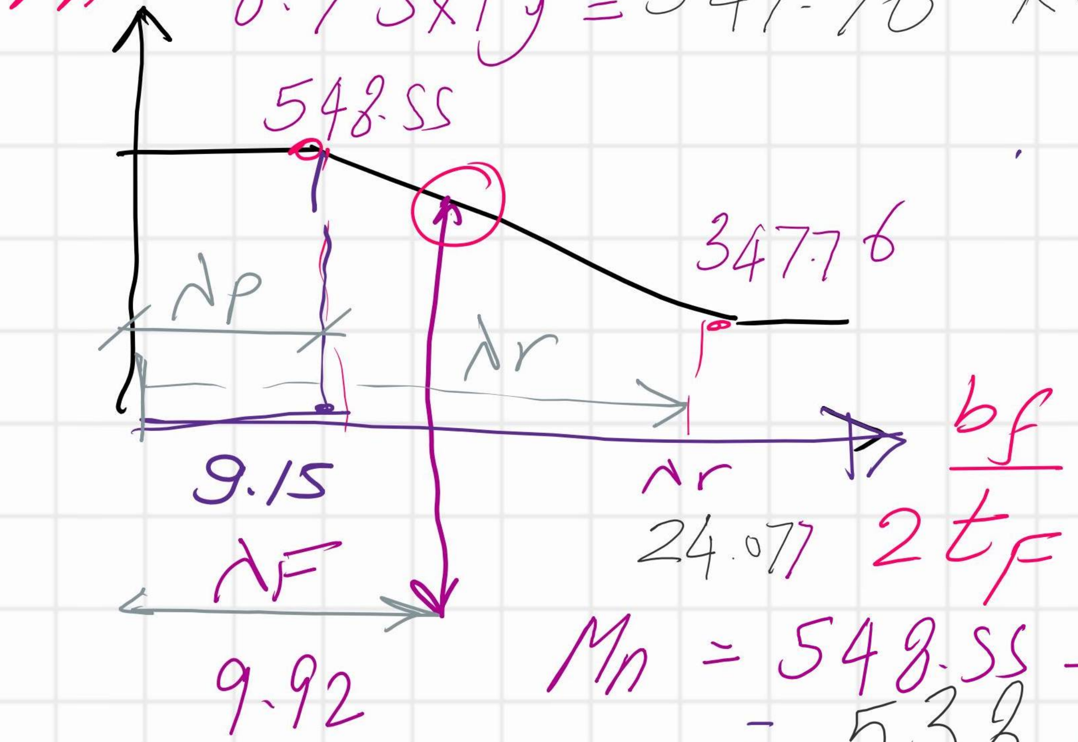
① Draw a graph between $\frac{b_f}{2t_f}$ & M_n

$M_n = M_p = 548.55$ kN·m

$0.7 S_x F_y = 347.76$ kN·m

$\frac{b_f}{2t_f} = 9.92$

W310 × 97



$\boxed{2}$ Find the Slope S

$$S = \left[\frac{548.55 - 347.76}{24.077 - 9.15}\right] = 13.451 \text{ kN·m}$$

$$M_n = F_y Z_x - S\left(\frac{b_f}{2t_f} - \lambda_p\right)$$

$$M_n = 548.55 - 13.451(9.92 - 9.15)$$

$$= 538.18 \text{ kN·m}$$

Find available moment strength

ⓐ LRFD value ⇒ $0.90(538.18) =$

$\phi_b M_n = 484.4$ kN·m

F3-section

F3 Section

W12X65 ⇒ W310X97 $M_p = 548.55$ KN.m

F3. DOUBLY SYMMETRIC I-SHAPED MEMBERS WITH COMPACT WEBS AND NONCOMPACT OR SLENDER FLANGES BENT ABOUT THEIR MAJOR AXIS

$M_n = 538.19$ KN.m

$F_y = 345$ MPA

The strength of shapes designed according to this section is limited by local buckling of the compression flange. Only a few standard wide-flange shapes have noncompact flanges. For these sections, the strength reduction for F_y = 50 ksi steel varies. The approximate percentages of M_p about the strong axis that can be developed by noncompact members when braced such that $L_b \le L_p$ are shown as follows:

W21×48 = 99%	W14×99 = 99%	W14×90 = 97%	W12×65 = 98%
W10×12 = 99%	W8×31 = 99%	W8×10 = 99%	W6×15 = 94%
W6×8.5 = 97%			

Ratio

The strength curve for the flange local buckling limit state, shown in Figure F-2, is similar in nature to that of the lateral-torsional buckling curve. The horizontal axis parameter is $\lambda = b_f/2t_f$. The flat portion of the curve to the left of λ_{pf} is the plastic yielding strength, M_p. The curved portion to the right of λ_{rf} is the strength limited by elastic

W12X65
W310X97

$$\frac{M_n}{M_P} = \frac{538.19}{548.55} \times 10^2 = 98.11\,\%$$

$\approx 98\,\%$

This is an excel sheet for non-compact sections

Excel data for non-compact sections

Non-compact sections- for W section -Fy=50 ksi

Type	EDI_Std_Nomenclature	E ksi	FY-ks	bf/2tf	h/tw	ambda	Z_x	S_x	r_y
W	W21X48	29000	50	9.47	53.6	9.15	107	93.0	1.66
W	W14X99	29000	50	9.34	23.5	9.15	173	157	3.71
W	W14X90	29000	50	10.2	25.9	9.15	157	143	3.70
W	W12X65	29000	50	9.92	24.9	9.15	96.8	87.9	3.02
W	W10X12	29000	50	9.43	46.6	9.15	12.6	10.9	0.785
W	W8X31	29000	50	9.19	22.3	9.15	30.4	27.5	2.02
W	W8X10	29000	50	9.61	40.5	9.15	8.87	7.81	0.841
W	W6X15	29000	50	11.5	21.6	9.15	10.8	9.72	1.45
W	W6X9	29000	50	9.16	29.2	9.15	6.23	5.56	0.905
W	W6X8.5	29000	50	10.1	29.1	9.15	5.73	5.10	0.890

Lateral torsional Buckling

What is Lp & Lr values?

What is the value for Lp?

$W12 \times 65 \Rightarrow W310 \times 57$

$$L_p = 1.76\, r_y \sqrt{\frac{E}{F_y}} = 1.76(76.70)\sqrt{\frac{2(10^5)}{345}} = 3250.25 \text{ mm}$$

$/10^3 \Rightarrow m$

$r_y = 76.70$ mm

$E = 2(10^5)\ \frac{N}{mm^2}$

$F_y = 345\ \frac{N}{mm^2}$

$L_p = 3.25\ m$

Lateral torsional Buckling

$S_x = 1440(10^3)\ mm^3$

Find Lr Valu

What is the value for Lr?

$$L_r = 1.95 r_{ts} \frac{E}{0.7F_y}\sqrt{\frac{Jc}{S_x h_o} + \sqrt{\left(\frac{Jc}{S_x h_o}\right)^2 + 6.76\left(\frac{0.7F_y}{E}\right)^2}} \quad \text{(F2-6)}$$

where

$$r_{ts}^2 = \frac{\sqrt{I_y C_w}}{S_x}$$

and the coefficient c is determined as follows:

(a) For doubly symmetric I-shapes: $c = 1$

(b) For channels: $c = \frac{h_o}{2}\sqrt{\frac{I_y}{C_w}}$ (F2-8b)

r_{ts}	h_o
85.9	292

J-10^3	Cw-10^6
907	1550

$C = 1$

$$L_r = 1.95(85.90)\frac{2\times10^5}{0.7(345)}\sqrt{\left(\frac{907000(1)}{1440(292)\,10^3}\right) + \sqrt{\left(\frac{907(10^3)}{1440(10)^3(292}\right)^2 + 6.76\left(\frac{0.7(345)}{2(10^5)}\right)^2}}$$

$L_r = 10715\ mm$

$\frac{1}{10^3}$

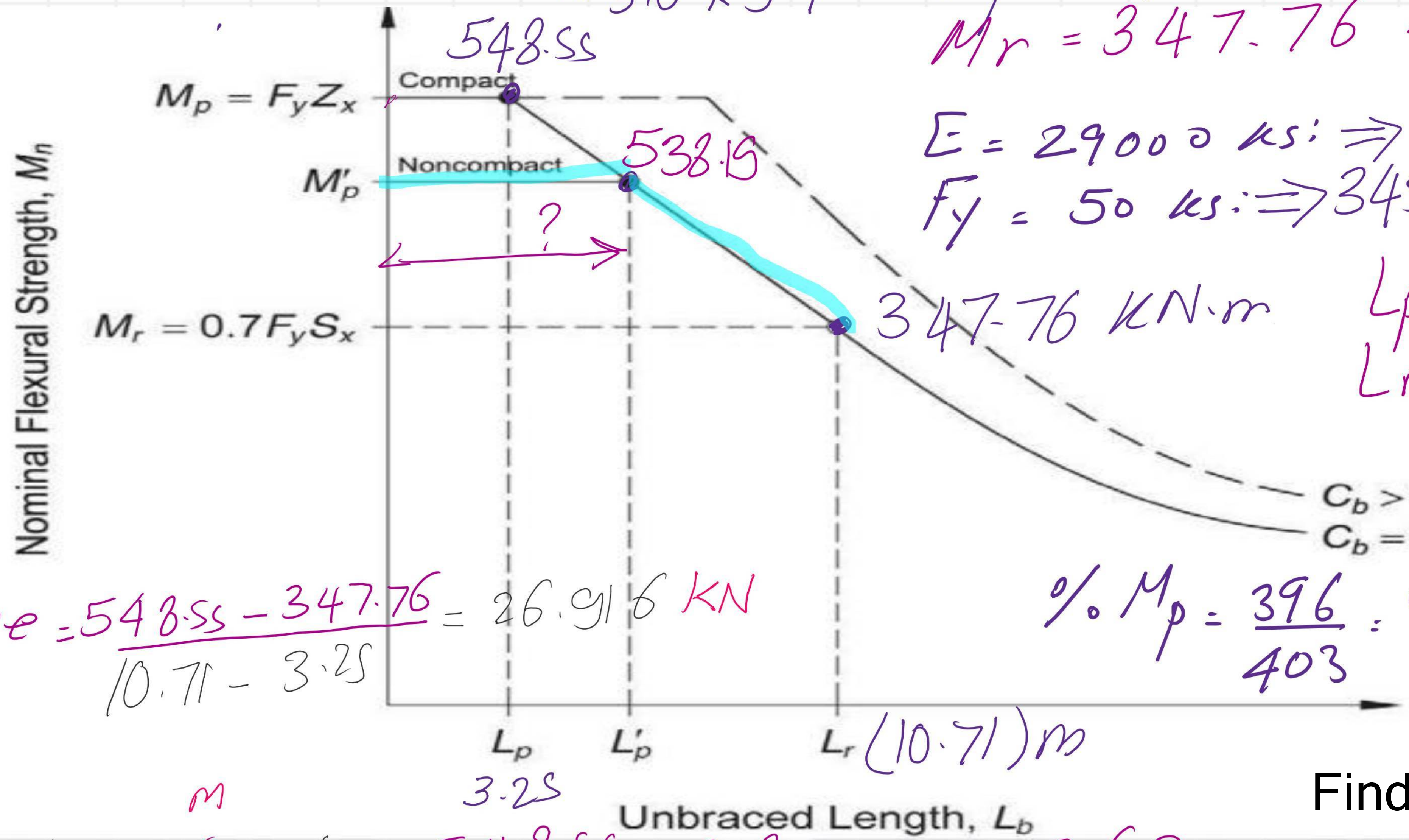
$L_r = 10.71\ m$

In our Case W12×65
W310×97

$M_p = 548.55$ kN·m
$M_r = 347.76$ kN·m

$E = 29000$ ksi $\Rightarrow 2(10^5)$ MPA
$F_y = 50$ ksi $\Rightarrow 345$ MPA

$L_p = 3.25$ m
$L_r = 10.71$ m



$$\text{Slope} = \frac{548.55 - 347.76}{10.71 - 3.25} = 26.916 \text{ KN}$$

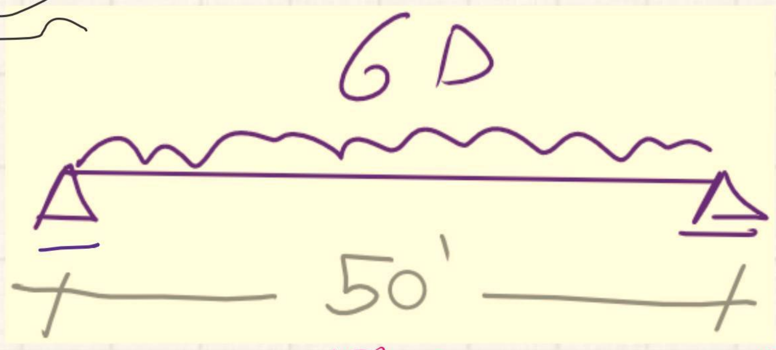
$$\% M_p = \frac{396}{403} = 98.26\% \approx 98\%$$

Find Lp' value

$$L_p' = 3.25\text{ m} + \left(\frac{548.55 - 538.19}{26.916}\right) = 3.63 \text{ m}$$

$W_{ult} = 1.2\ D + 1.6\ L$ LRFD

$\frac{L}{D} = 3$ $\Rightarrow W_{ult} = 1.4\ D$



$W_{UL} = D\left(1.2 + \frac{L}{D}(1.60)\right)$

$W_{ult} = D\,(1.2 + 4.80) = 6\ D$

15.25 m

Equate $M_{ult} \Rightarrow \phi_b M_n$

$M_{ult} = W_U L^2/8$

$= 6\ \frac{D(15.25)^2}{8} \leq \phi_b M_n$

Total service Load LRFD

$= 0.9(538.19)$ KN.m

$D = 8\,(0.9)(538.19)/6(15.25)^2 \Rightarrow 2.77$ KN/m

$\Rightarrow L = 3D = 3(2.77) = 8.31$ KN/m

$D + L = 2.77 + 8.31 = 11.08$ KN/m
Service Load

$L/D = 3$

Part (b) ASD

$D + L = D + 3D = 4D$

Total service Load ASD

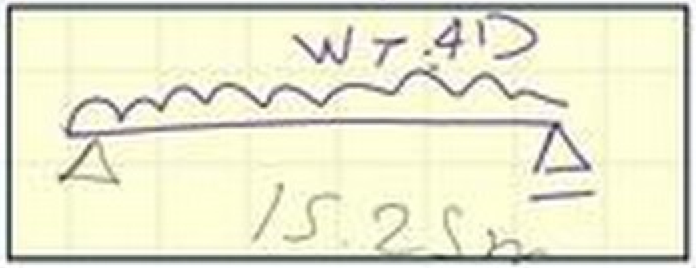
$L = 50' \Rightarrow 15.25\,m$

$$\frac{M_n}{\Omega} = \frac{538.19}{1.67} = 322.30\ KN.m$$

but $\dfrac{L}{D} = 3 \rightarrow W_T = W_D + W_L = D + L$

$W_T = D + 3D = 4D$

$$W_T \cdot \frac{l^2}{8} \leq \frac{M_n}{\Omega_b} \Rightarrow \frac{4D(15.25)^2}{8} = 322.30\ KN.m$$



$$D = \frac{322.30(8)}{4(15.25)^2} = 2.77\ KN/m$$

$L = 3(2.77 = 8.32\ \frac{KN}{m}$

$D + L = 11.09\ KN/m$