

How to Find L_p ?

① For the calculation of $L_p = 300 \frac{r_y}{\sqrt{F_y}}$
but we need Table 1-1 For
A given W-section to get r_y .

② We can use Table 3-2 where W sections
are sorted by Z_x , but we need Z_x
value from Table 1-1.

Important definitions

L_r: Limiting Laterally un-braced Length for the Limit state
For inelastic Lateral Torsional buckling, LTB.

How to estimate?

J, C, S_x, h_o, r_{ts} From Table 1-1

① From Equation

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

F2-6

2nd
part

where

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

(F2-7)

L_r
or Frame table

and the coefficient c is determined as follows:

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

(F2-8a)

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

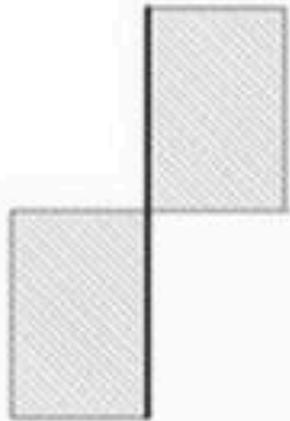
(F2-8b)

3-2
For W sections
based on Z_x

but we need Z_x
From Table 1-1

L_b From 0
= L_p

ZONE 1
Plastic Behavior
Full Plastic Moment

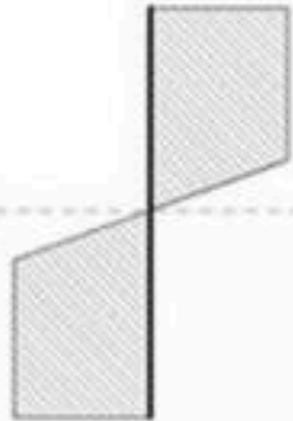


$$M_n = M_p = F_y Z \leq 1.5 M_y$$

$$M_u = C_b M_n$$

$L_b > L_p$

ZONE 2
Inelastic Buckling
More than First Yield
Less than Full Plastic Moment

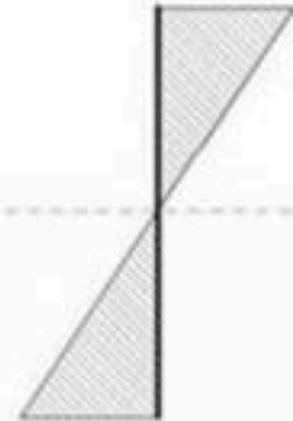


$$M_n = C_b \left(M_p - (M_p - M_r) \left(\frac{L_b - L_p}{L_r - L_p} \right) \right) < M_p$$

$$M_u = C_b M_n$$

$L_b = L_r$

First Yield



$$M_r = 0.7 F_y S_x$$

$$M_u \leq C_b M_r$$

$L_b > L_r$

ZONE 3
Elastic Buckling



$$M_{cr} = C_b \frac{\pi}{L_c} \sqrt{E I_y G J + \left(\frac{\pi E}{L_c} \right)^2 I_y C_w}$$

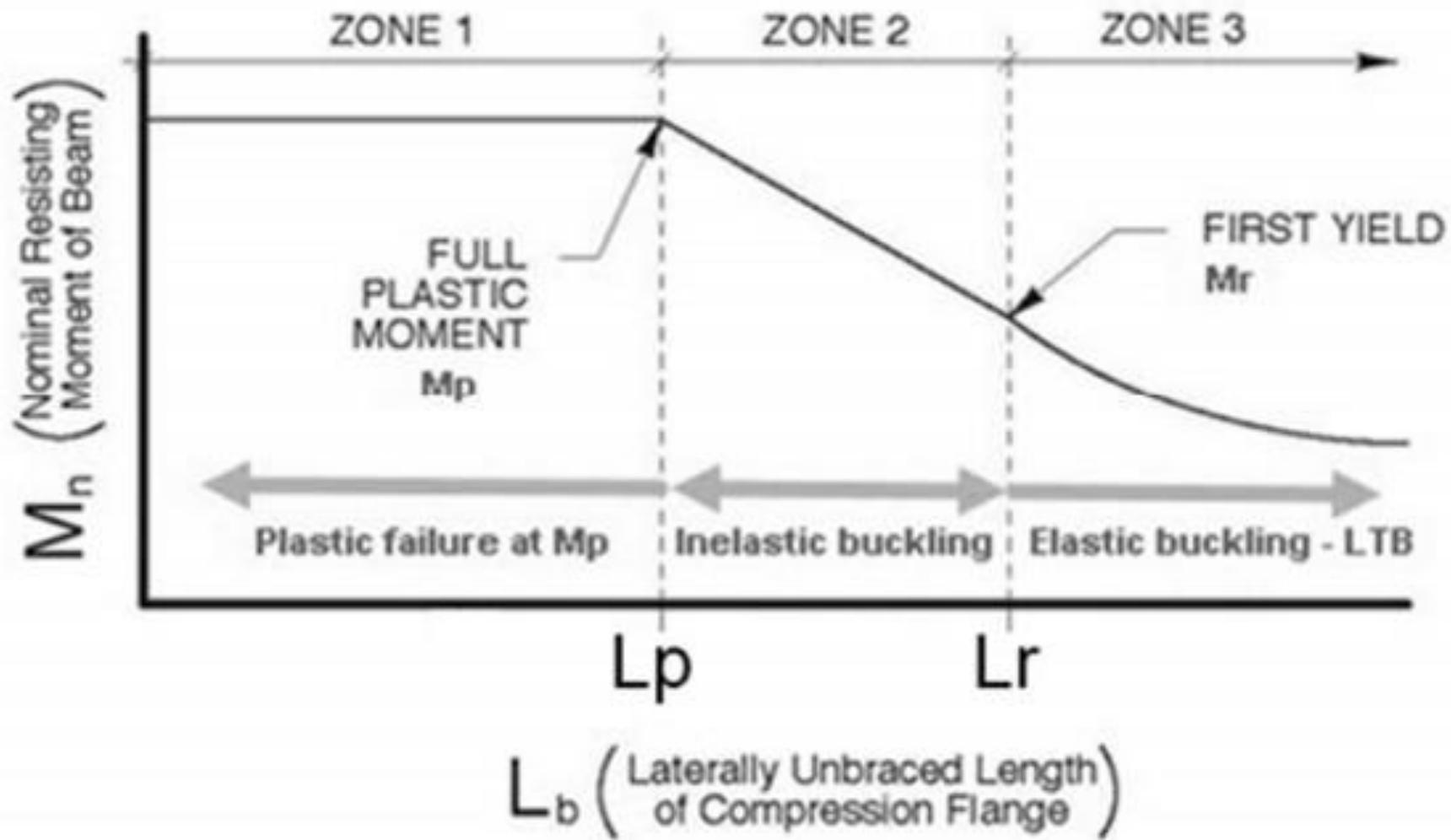
$$M_u \leq C_b M_{cr}$$

The different zones

$$\phi_b = 0.90$$

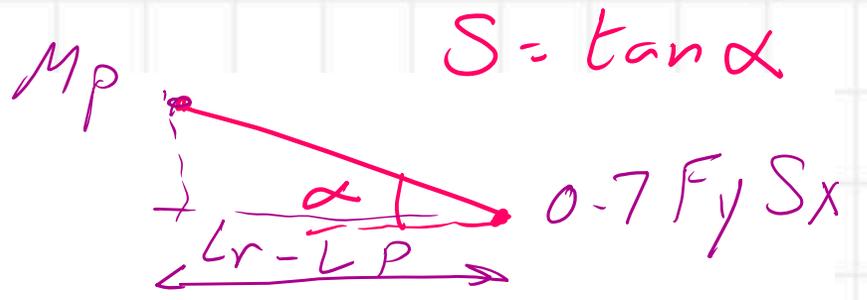
LRFD

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Nominal L strength moment M_n



2. Lateral-Torsional Buckling

- (a) When $L_b \leq L_p$, the limit state of lateral-torsional buckling does not apply.
- (b) When $L_p < L_b \leq L_r$

$$M_n = C_b \left[M_p - (M_p - 0.7 F_y S_x) \left(\frac{L_b - L_p}{L_r - L_p} \right) \right] \leq M_p \quad (F2-2)$$

- (c) When $L_b > L_r$

$$M_n = F_{cr} S_x \leq M_p \quad (F2-3)$$

where

L_b = length between points that are either braced against lateral displacement of the compression flange or braced against twist of the cross section, in. (mm)

$$F_{cr} = \frac{C_b \pi^2 E}{\left(\frac{L_b}{r_{ts}} \right)^2} \sqrt{1 + 0.078 \frac{Jc}{S_x h_o} \left(\frac{L_b}{r_{ts}} \right)^2} \quad (F2-4)$$

L_b : the distance between bracings, or the unbraced length.

F_{cr} : Stress for beam when $L_b > L_r$

Practice problem

① It is required to Find the Following For W24x176
 For $F_y = 36$ ks, L_p , L_r , M_p and M_r Values.

Solution

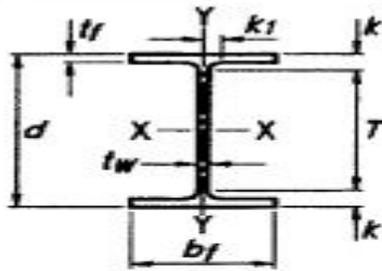
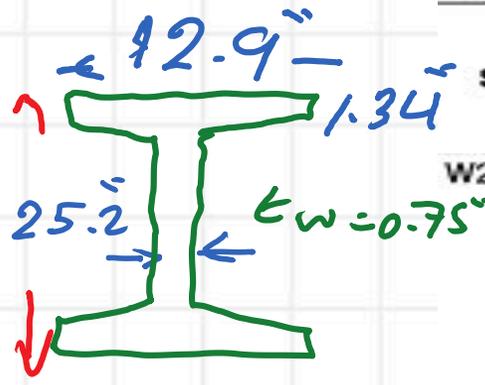


Table 1-1 (continued)
W-Shapes
 Dimensions



Shape	Area, A in. ²	Depth, d in.	Web		Flange		Distance				Workable Gage in.				
			Thickness, t _w in.	t _w /2 in.	Width, b _f in.	Thickness, t _f in.	k		k ₁ in.	T in.					
							k _{des} in.	k _{det} in.							
W24x370 ^h	109	28.0	28	1.52	1 1/2	3/4	13.7	13 5/8	2.72	2 3/4	3.22	3 5/8	1 9/16	20 3/4	5 1/2
x335 ^h	98.3	27.5	27 1/2	1.38	1 3/8	1 1/16	13.5	13 1/2	2.48	2 1/2	2.98	3 3/8	1 1/2		
x306 ^h	89.7	27.1	27 1/8	1.26	1 1/4	5/8	13.4	13 3/8	2.28	2 1/4	2.78	3 3/16	1 7/16		
x279 ^h	81.9	26.7	26 3/4	1.16	1 3/16	5/8	13.3	13 1/4	2.09	2 1/16	2.59	3	1 7/16		
x250	73.5	26.3	26 3/8	1.04	1 1/16	9/16	13.2	13 1/8	1.89	1 7/8	2.39	2 13/16	1 3/8		
x229	67.2	26.0	26	0.960	15/16	1/2	13.1	13 1/8	1.73	1 3/4	2.23	2 5/8	1 5/16		
x207	60.7	25.7	25 3/4	0.870	7/8	7/16	13.0	13	1.57	1 9/16	2.07	2 1/2	1 1/4		
x192	56.5	25.5	25 1/2	0.810	13/16	7/16	13.0	13	1.46	1 7/16	1.96	2 3/8	1 1/4		
x176	51.7	25.2	25 1/4	0.750	3/4	3/8	12.9	12 7/8	1.34	1 5/16	1.84	2 1/4	1 3/16		

$$W24 \times 167 \rightarrow F_y = 36 \text{ ksi}$$

Nominal Wt.	Compact Section Criteria		Axis X-X				Axis Y-Y				r_{ts}	h_o	Torsional Properties	
	$\frac{b_f}{2t_f}$	$\frac{h}{t_w}$	I	S	r	Z	I	S	r	Z			J	C_w
lb/ft			in. ⁴	in. ³	in.	in. ³	in. ⁴	in. ³	in.	in. ³	in.	in.	in. ⁴	in. ⁶
370	2.51	14.2	13400	957	11.1	1130	1160	170	3.27	267	3.92	25.3	201	186000
335	2.73	15.6	11900	864	11.0	1020	1030	152	3.23	238	3.86	25.0	152	161000
306	2.94	17.1	10700	789	10.9	922	919	137	3.20	214	3.81	24.8	117	142000
279	3.18	18.6	9600	718	10.8	835	823	124	3.17	193	3.76	24.6	90.5	125000
250	3.49	20.7	8490	644	10.7	744	724	110	3.14	171	3.71	24.4	66.6	108000
229	3.79	22.5	7650	588	10.7	675	651	99.4	3.11	154	3.67	24.3	51.3	96100
207	4.14	24.8	6820	531	10.6	606	578	88.8	3.08	137	3.62	24.1	38.3	84100
192	4.43	26.6	6260	491	10.5	559	530	81.8	3.07	126	3.60	24.0	30.8	76300
176	4.81	28.7	5680	450	10.5	511	479	74.3	3.04	115	3.57	23.9	23.9	68400

W24
x
→

$$r_y = 3.04 \text{ inch} \rightarrow L_p = 300 \frac{r_y}{\sqrt{F_y}} = 300 \frac{3.04}{\sqrt{36}} = 152'$$

$$L_p = 152 \left(\frac{1F}{12} \right) = 12.66' \approx 12.70'$$

W24 x 167 → $F_y = 36 \text{ ksi}$

W24
x
→

Nominal Wt.	Compact Section Criteria		Axis X-X				Axis Y-Y				r_{ts}	h_o	Torsional Properties	
	$\frac{b_f}{2t_f}$	$\frac{h}{t_w}$	I	S	r	Z	I	S	r	Z			J	C_w
lb/ft			in. ⁴	in. ³	in.	in. ³	in. ⁴	in. ³	in.	in. ³	in.	in.	in. ⁴	in. ⁶
370	2.51	14.2	13400	957	11.1	1130	1160	170	3.27	267	3.92	25.3	201	186000
335	2.73	15.6	11900	864	11.0	1020	1030	152	3.23	238	3.86	25.0	152	161000
306	2.94	17.1	10700	789	10.9	922	919	137	3.20	214	3.81	24.8	117	142000
279	3.18	18.6	9600	718	10.8	835	823	124	3.17	193	3.76	24.6	90.5	125000
250	3.49	20.7	8490	644	10.7	744	724	110	3.14	171	3.71	24.4	66.6	108000
229	3.79	22.5	7650	588	10.7	675	651	99.4	3.11	154	3.67	24.3	51.3	96100
207	4.14	24.8	6820	531	10.6	606	578	88.8	3.08	137	3.62	24.1	38.3	84100
192	4.43	26.6	6260	491	10.5	559	530	81.8	3.07	126	3.60	24.0	30.8	76300
176	4.81	28.7	5680	450	10.5	511	479	74.3	3.04	115	3.57	23.9	23.9	68400

$r_y = 3.04 \text{ inch}^2$, $r_{ts} = 3.57''$, $S_x = 450 \text{ inch}^3$

$h_o = 23.9''$, $J = 23.90 \text{ inch}^4$

$C_w = 68400$

$Z_x = 511 \text{ inch}^3$

$$F_y = 36 \text{ ksi}$$

$$L_r = 1.95 r_{ts} \left(\frac{E}{0.70 F_y} \right) \sqrt{\frac{Jc}{S_x h_o} + \sqrt{\frac{(Jc)^2}{(S_x h_o)^2} + 6.76 \left(\frac{0.7 F_y}{E} \right)^2}}$$

$$r_y = 3.04 \text{ inch}^2, r_{ts} = 3.57'', S_x = 450 \text{ inch}^3$$

$$h_o = 23.9'', J = 23.90 \text{ inch}^4, C = 1$$

$$C_w = 68400$$

$$L_r = 1.95 (3.57) \left(\frac{29000}{0.7(36)} \right) \sqrt{\frac{23.90}{(450)(23.90)} + \sqrt{\left(\frac{23.90}{450(23.90)} \right)^2 + 6.76 \left(\frac{0.7(36)}{29000} \right)^2}}$$

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For W24 x 176

$$L_r = \frac{32045}{4} \sqrt{(0.002222) + 0.003169}$$

$$L_r = 588.21'' \approx 588'' \rightarrow 49.01'$$

$$Z_x = 511.0 \text{ inch}^3$$

$$f_y = 36 \text{ ksi}$$

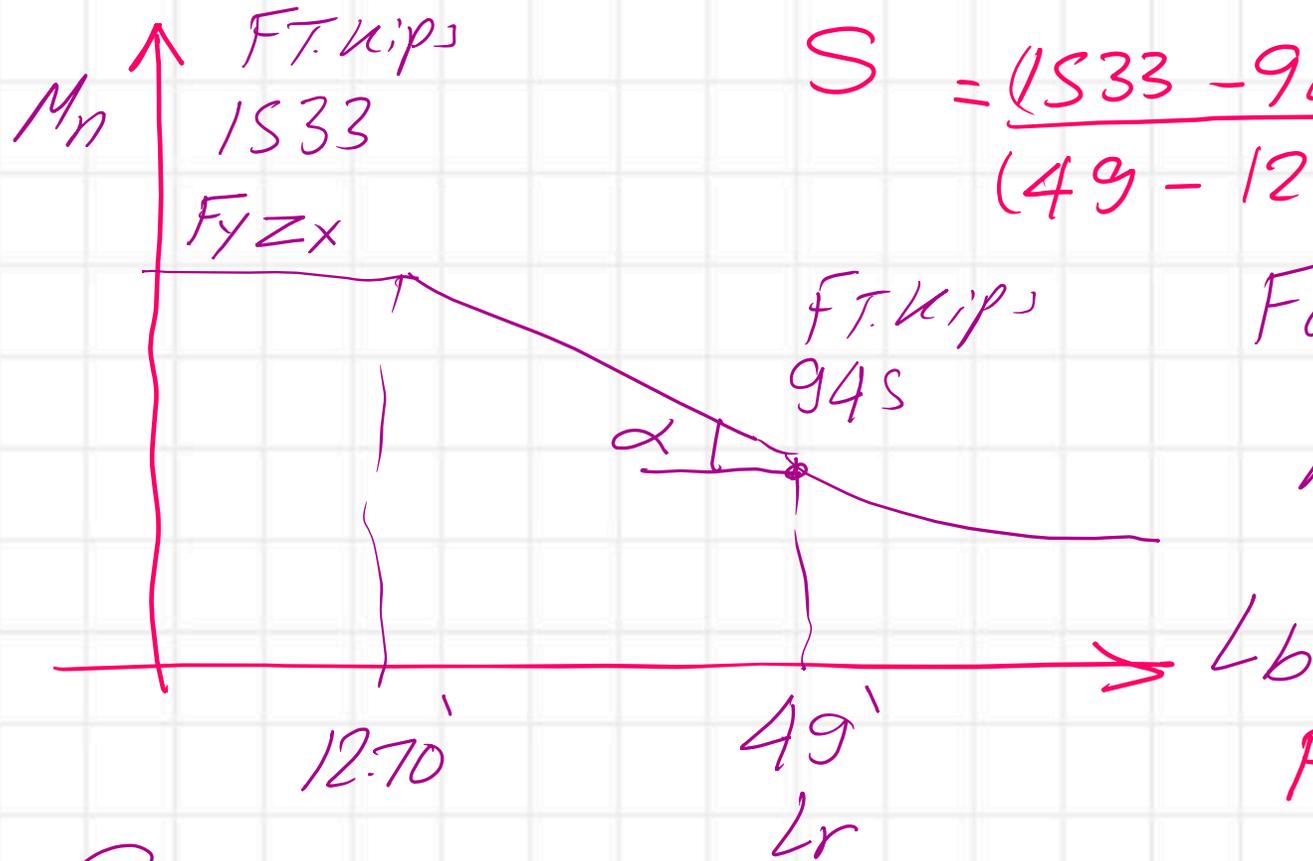
$$S_x = 450 \text{ inch}^3$$

$$M_p = F_y Z_x = 36(511) \left(\frac{1}{12}\right) = 1533.0 \text{ Ft.kips}$$

$$M_r = (0.70 f_y) S_x$$

$$= 0.70(36) \left(\frac{450}{12}\right) = 945.0 \text{ Ft.kips}$$

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$$S = \frac{(1533 - 945)}{(49 - 12.70)} = 16.1983 \approx \tan \alpha$$

For $L_b > 12.7'$
 $< 49'$

$$M_n = 1533 - S(L_b - 12.70)$$

For 16' \Rightarrow

$$M_n = 1533 - 16.1983(16 - 12.7)$$

$$= 1479.55 \text{ FT.kip}$$

$$\approx 1480 \text{ FT.kip}$$

$$C_b = 1$$

W 24 x 176

$$F_y = 36 \text{ ksi}$$

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For $L_b > L_r$

$$L_r = 49'$$

$$L_b = 50'$$

$$\frac{L_b}{r_{ts}} = \frac{50(12)}{(3.57)}$$

$$= \left(\frac{600}{3.57}\right)$$

$$F_{cr} = \frac{C_b \pi^2 E}{\left(\frac{L_b}{r_{ts}}\right)^2} \sqrt{1 + 0.078 \frac{Jc}{S_x h_o} \left(\frac{L_b}{r_{ts}}\right)^2}$$

$$M_n = F_{cr} S_x$$

$L_b = 50'$

$$F_{cr} = \frac{(1)(3.14159)^2 29000}{\left(\frac{600}{3.57}\right)^2}$$

$$\sqrt{1 + 0.078 \frac{(23.9)(1.0)}{(450)(23.9)} \left(\frac{600}{3.57}\right)^2}$$

$F_{cr} \quad S_x \quad \text{inch. kips}$

$$\approx 24.672 \text{ ksi} \Rightarrow M_n = 24.672(450) = 11102.4$$

$$\Rightarrow \frac{1}{12} = 925.2 \text{ FT. kips}$$

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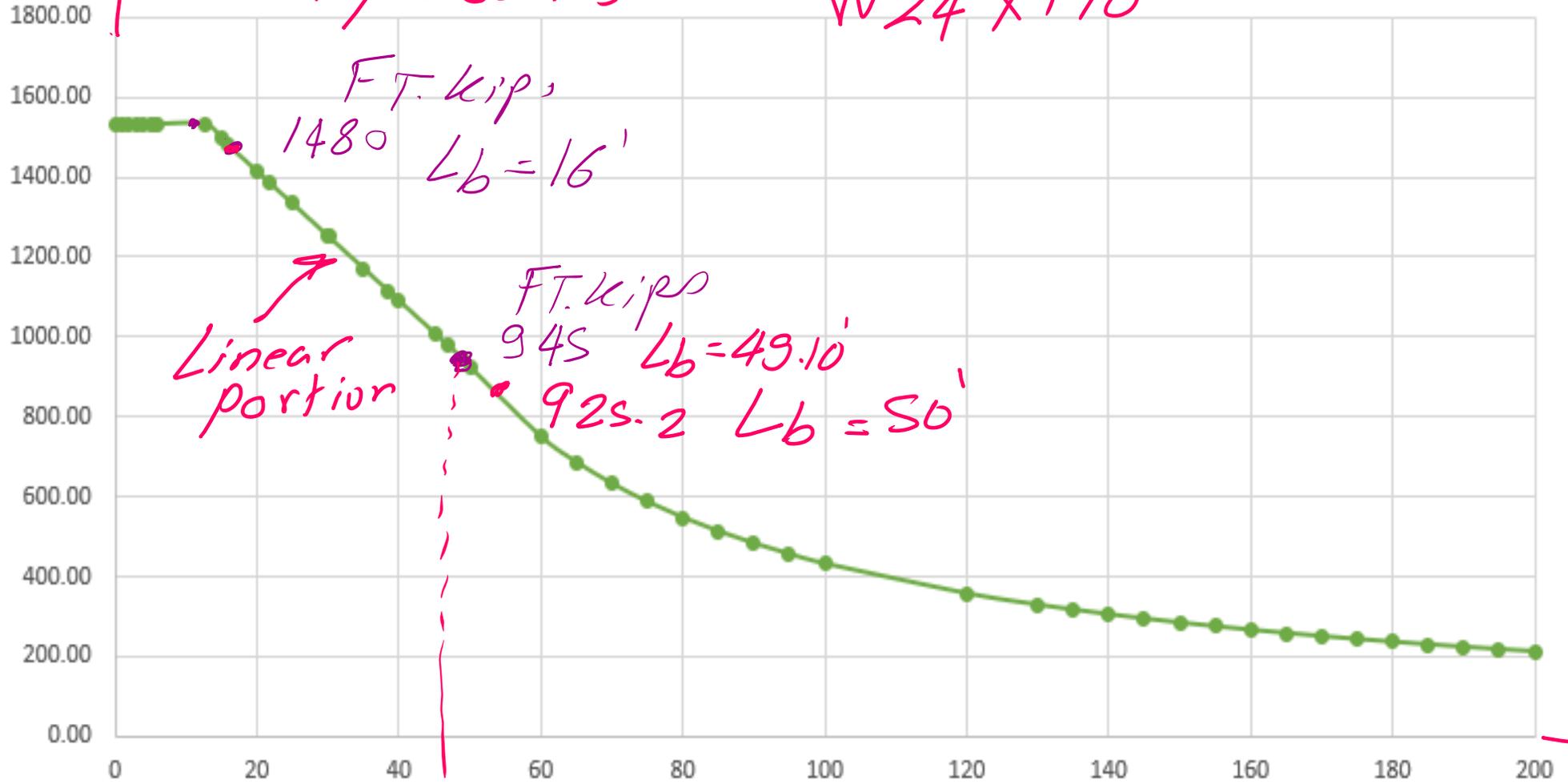
M_p
1533

M_n ↑

$F_y = 36 \text{ ksi}$

W24 x 176

Chart Title



→
 L_b

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