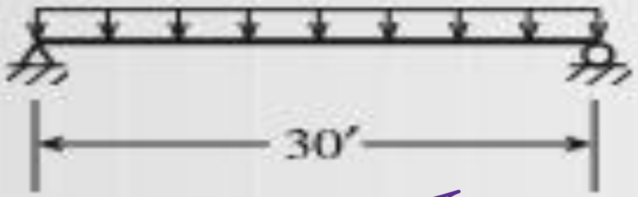
5.3 → segui

The beam shown in Figure 5.11 is a W16 × 31 of A992 steel. It supports a reinforced concrete floor slab that provides continuous lateral support of the compression flange. The service dead load is 450 lb/ft. This load is superimposed on the beam; it does not include the weight of the beam itself. The service live load is 550 lb/ft. Does this beam have adequate moment strength?

Analysis Example



w_D = 450 lb/ft
w_L = 550 lb/ft

$L_b = 0 \rightarrow$ Continuous Lateral Support

$F_y = 50$ ksi

ASTM A 992 $\Rightarrow F_y = 50$ ksi

$E = 29{,}000$ ksi

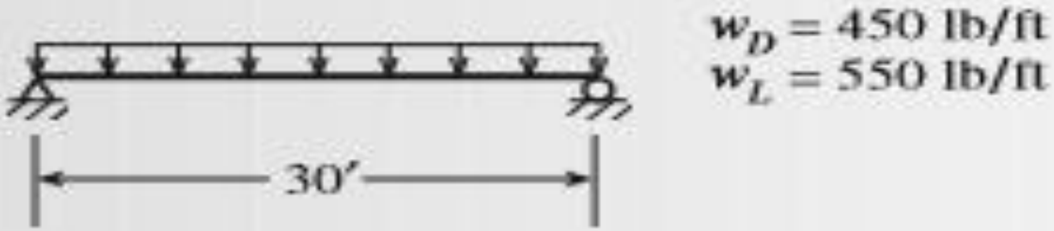
Element	λ	λ_p	λ_r
Flange	$\frac{b_f}{2t_f}$	$0.38\sqrt{\frac{E}{F_y}}$	$1.0\sqrt{\frac{E}{F_y}}$
Web	$\frac{h}{t_w}$	$3.76\sqrt{\frac{E}{F_y}}$	$5.70\sqrt{\frac{E}{F_y}}$

Check that: 1 Flange is Compact
2 Web is Compact

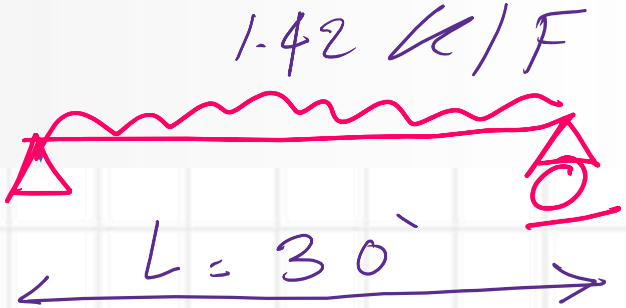
Prepared by Eng.Maged Kamel.

5.3 → segui

The beam shown in Figure 5.11 is a W16 × 31 of A992 steel. It supports a reinforced concrete floor slab that provides continuous lateral support of the compression flange. The service dead load is 450 lb/ft. This load is superimposed on the beam; it does not include the weight of the beam itself. The service live load is 550 lb/ft. Does this beam have adequate moment strength?



Analysis Example



@ LRFD ⇒ include own wt

$w_b = 31 \frac{lb}{FT}$

$W_{ult} = 1.2\, w_D + 1.6\, L$

$1.2\,(0.450 + 0.031) + 1.6\,(0.55)$

$0.5772 + 0.88 = 1.4572$

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

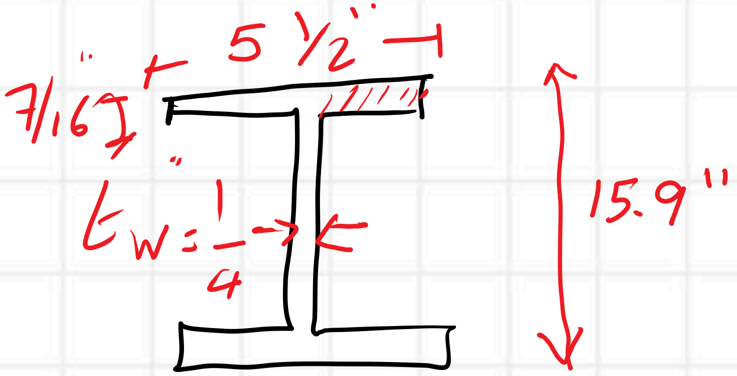
$= \frac{1.4572\,(900)}{8}$

$= 163.935$

$\simeq 164$ FT. kips

Table 1-1

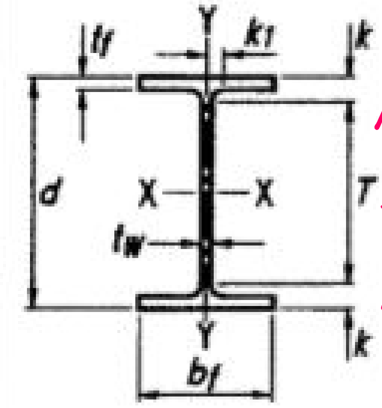
Shape	Area, A	Depth, d		Web Thickness, t_w		$\frac{t_w}{2}$	Flange Width, b_f		Flange Thickness, t_f		Distance k: k_{des}	k_{det}	k_1	T	Workable Gage
	in.^{2}	in.		in.		in.	in.		in.		in.	in.	in.	in.	in.
W16×31^c	9.13	15.9	15 7/8	0.275	1/4	1/8	5.53	5 1/2	0.440	7/16	0.842	1 1/8	3/4	13 5/8	3 1/2
×26^{c,v}	7.68	15.7	15 3/4	0.250	1/4	1/8	5.50	5 1/2	0.345	3/8	0.747	1 1/16	3/4	13 5/8	3 1/2



Nom-inal Wt.	Compact Section Criteria: $\frac{b_f}{2t_f}$	$\frac{h}{t_w}$	Axis X-X: I	S	r	Z	Axis Y-Y: I	S	r	Z	r_{ts}	h_o	Torsional Properties: 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}
31	6.28	51.6	375	47.2	6.41	54.0	12.4	4.49	1.17	7.03	1.42	15.5	0.461	739
26	7.97	56.8	301	38.4	6.26	44.2	9.59	3.49	1.12	5.48	1.38	15.4	0.262	565

From table $\frac{b_f}{2t_f} = 6.28$

$\frac{h}{t_F} = 51.60$



λ_p

Flange is Compact

λ_p Flange $0.38\sqrt{\frac{E}{F_y}} = 0.38\sqrt{\frac{29000}{50}} = 9.15$

λ_p web $3.76\sqrt{\frac{E}{F_y}} = 3.76\sqrt{\frac{29 \times 10^3}{50}} = 90.55$

$\frac{b_f}{2t_f} < 9.15$ λ_{pF}

$\frac{h}{t_f} < 90.55$ λ_{pw}

compact web

Prepared by Eng.Maged Kamel.

Find M_p $\phi_b = 0.90$

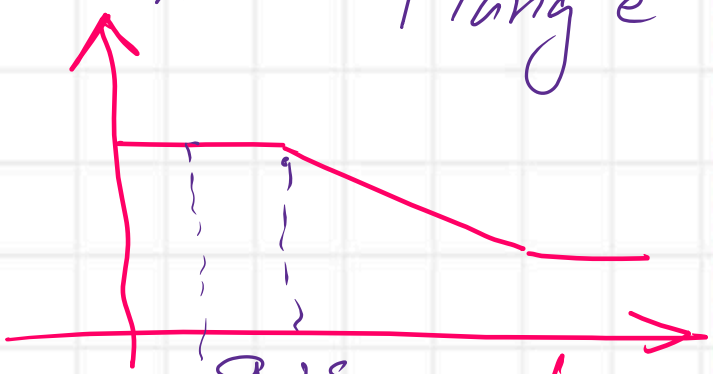
@LRFD Design

$M_n = M_p = f_y \cdot Z_x = 50(54) = 2700$ kips. inch

$M_n = 2700$ kip . inch $\left(\frac{ft}{12 inch}\right) = 225$ kips . Ft

$M_{ult} \leq \phi M_n = 0.90(225) = 202.50$ kip.ft

Nom-inal 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}
31	6.28	51.6	375	47.2	6.41	54.0	12.4	4.49	1.17	7.03	1.42	15.5	0.461	739
26	7.97	56.8	301	38.4	6.26	44.2	9.59	3.49	1.12	5.48	1.38	15.4	0.262	565



Compare with $M_u = 164$ FT. kips

$M_u < 202.50$ FT. kips

Section is adequate

Prepared by Eng.Maged Kamel.

Using ASD

$w_D = (450 + 31) = 481 \ Lb/ft$ $\qquad \Omega_b = 1.67$

$w_L = 550 \ Lb/ft$

$M_D + M_L = \left[(481) + (550)\right] \frac{\overline{30}^2}{8} (10^{-3}) \simeq 116.0 \ kips.ft$

$\Omega = 1.67$ $\qquad$ From before $M_n = 225.0 \ kips.ft$

$M_{allowable} = \frac{M_n}{\Omega} = \frac{225}{1.67} = 135 \ kips.ft$

while $M_{D+L} = 116.0 \ kips.ft$ $\qquad 135 > 116$

$M_{all} > M_{D+L}$ it is safe

Prepared by Eng.Maged Kamel.

Check Compactness Lindeburg W21 X 55 A992 steel

$b_f/2t_f$

Example

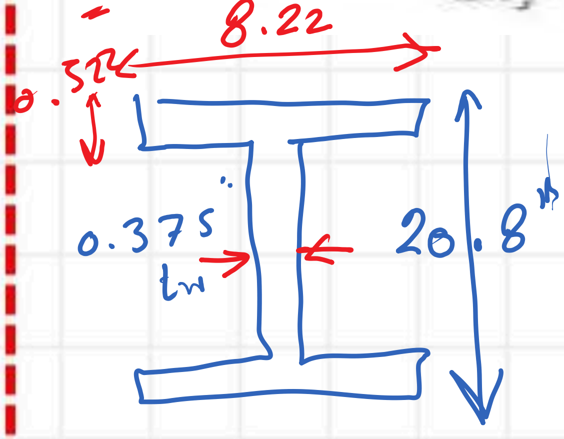
Establish whether a W21 × 55 beam of A992 steel is compact.

(A) $\frac{b_f}{2t_f} < \lambda_{pf}$ and $\frac{h}{t_w} < \lambda_{pw}$; beam is compact

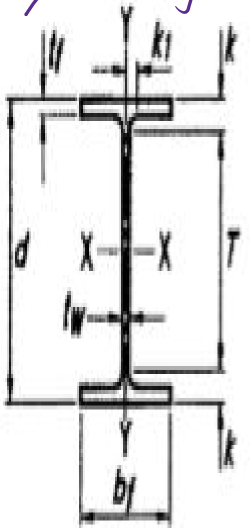
(B) $\frac{b_f}{2t_f} < \lambda_{pf}$ and $\frac{h}{t_w} > \lambda_{pw}$; beam is not compact

(C) $\frac{b_f}{2t_f} > \lambda_{pf}$ and $\frac{h}{t_w} < \lambda_{pw}$; beam is compact

(D) $\frac{b_f}{2t_f} > \lambda_{pf}$ and $\frac{h}{t_w} > \lambda_{pw}$; beam is not compact



Shape	Area, A	Depth, d		Web Thickness, t_w		Web $\frac{t_w}{2}$	Flange Width, b_f		Flange Thickness, t_f		Distance k_{des}	Distance k_{det}	k_1	T	Workable Gage
	in.²	in.		in.		in.	in.		in.		in.	in.	in.	in.	in.
W21×93	27.3	21.6	21 5/8	0.580	9/16	5/16	8.42	8 3/8	0.930	15/16	1.43	1 5/8	15/16	18 3/8	5 1/2
×83[c]	24.4	21.4	21 3/8	0.515	1/2	1/4	8.36	8 3/8	0.835	13/16	1.34	1 1/2	7/8		
×73[c]	21.5	21.2	21 1/4	0.455	7/16	1/4	8.30	8 1/4	0.740	3/4	1.24	1 7/16	7/8		
×68[c]	20.0	21.1	21 1/8	0.430	7/16	1/4	8.27	8 1/4	0.685	11/16	1.19	1 3/8	7/8		
×62[c]	18.3	21.0	21	0.400	3/8	3/16	8.24	8 1/4	0.615	5/8	1.12	1 5/16	13/16		
×55[c]	16.2	20.8	20 3/4	0.375	3/8	3/16	8.22	8 1/4	0.522	1/2	1.02	1 3/16	13/16		
×48[c,f]	14.1	20.6	20 5/8	0.350	3/8	3/16	8.14	8 1/8	0.430	7/16	0.930	1 1/8	13/16		



$f_y = 50$ ksi

$$\frac{B_F}{2t_F} = \frac{8.22}{2(0.522)} = 7.87$$

$$\lambda_{PF} = 64.7/\sqrt{F_y} = 64.7/\sqrt{50} = 9.15$$

Prepared by Eng.Maged Kamel.

Find h/t_w

Example

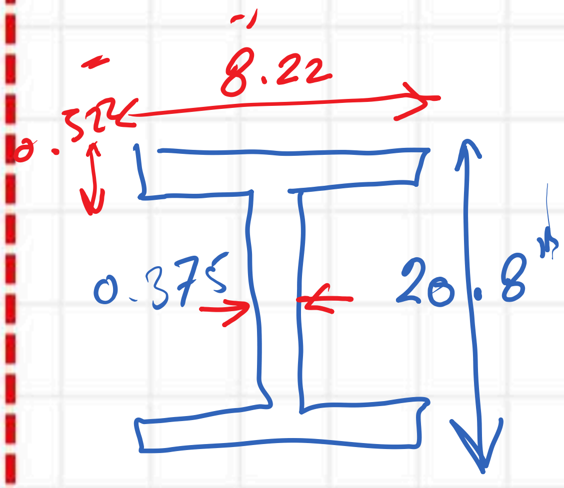
Establish whether a W21 × 55 beam of A992 steel is compact.

(A) $\frac{b_f}{2t_f} < \lambda_{pf}$ and $\frac{h}{t_w} < \lambda_{pw}$; beam is compact ok

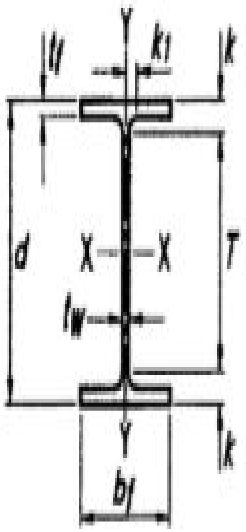
(B) $\frac{b_f}{2t_f} < \lambda_{pf}$ and $\frac{h}{t_w} > \lambda_{pw}$; beam is not compact x

(C) $\frac{b_f}{2t_f} > \lambda_{pf}$ and $\frac{h}{t_w} < \lambda_{pw}$; beam is compact x

(D) $\frac{b_f}{2t_f} > \lambda_{pf}$ and $\frac{h}{t_w} > \lambda_{pw}$; beam is not compact x



Shape	Area, A	Depth, d		Web Thickness, t_w		$\frac{t_w}{2}$	Flange Width, b_f		Flange Thickness, t_f		Distance k_{des}	k_{det}	k_1	T	Workable Gage
	in.^{2}	in.		in.		in.	in.		in.		in.	in.	in.	in.	in.
W21×93	27.3	21.6	21 5/8	0.580	9/16	5/16	8.42	8 3/8	0.930	15/16	1.43	1 5/8	15/16	18 3/8	5 1/2
×83c	24.4	21.4	21 3/8	0.515	1/2	1/4	8.36	8 3/8	0.835	13/16	1.34	1 1/2	7/8		
×73c	21.5	21.2	21 1/4	0.455	7/16	1/4	8.30	8 1/4	0.740	3/4	1.24	1 7/16	7/8		
×68c	20.0	21.1	21 1/8	0.430	7/16	1/4	8.27	8 1/4	0.685	11/16	1.19	1 3/8	7/8		
×62c	18.3	21.0	21	0.400	3/8	3/16	8.24	8 1/4	0.615	5/8	1.12	1 5/16	13/16		
×55c	16.2	20.8	20 3/4	0.375	3/8	3/16	8.22	8 1/4	0.522	1/2	1.02	1 3/16	13/16		
×48c,f	14.1	20.6	20 5/8	0.350	3/8	3/16	8.14	8 1/8	0.430	7/16	0.930	1 1/8	13/16		



$f_y = 50\,ksi$

$$\frac{h}{t_w} = \frac{(20.80 - 2(0.522))}{0.375} = 52.7 \longleftrightarrow \frac{640}{\sqrt{F_y}} = \frac{640}{\sqrt{50}} = 90.55$$

λ_{pw}

Prepared by Eng.Maged Kamel.

Since $\frac{b_F}{2t_F} < \lambda_{pF}$ & $\frac{h_w}{t_w} < \lambda_{pw}$

Flange is Compact
web is Compact

whole section is Compact

Option A is selected