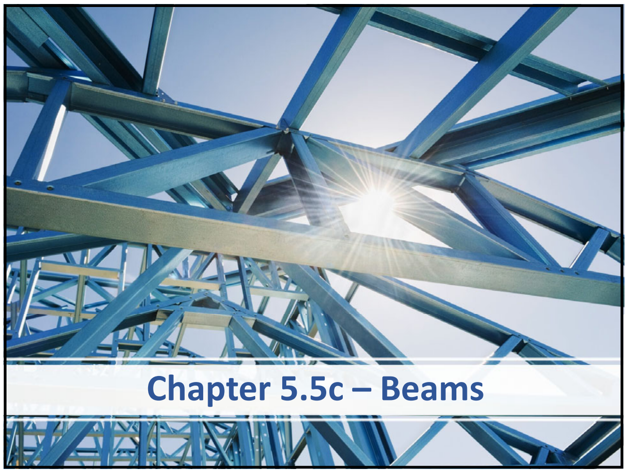

1

Chapter 5 – Compact Shapes

- Recall, the nominal bending strength for compact ***I*** and ***C***-shaped sections can be summarized as follows:

For $L_b \le L_p$ $\quad M_n = M_p$ ***AISC Equation F2-1***

For $L_p < L_b \le L_r$ $\quad M_n = C_b\left[M_p - \left(M_p - 0.7F_yS_x\right)\left(\frac{L_b - L_p}{L_r - L_p}\right)\right] \le M_p$

AISC Equation F2-2

For $L_b > L_r$ $\quad M_n = F_{cr}S_x \le M_p$ ***AISC Equation F2-3***

$$F_{cr} = \frac{C_b\pi^2 E}{\left(L_b/r_{ts}\right)^2}\sqrt{1 + 0.078\frac{Jc}{S_xh_0}\left(\frac{L_b}{r_{ts}}\right)^2}$$ ***AISC Equation F2-4***

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Chapter 5 – Compact Shapes

- Remember that C_b is a ***lateral-torsional buckling modification factor*** that accounts for nonuniform bending within the unbraced length L_b.

For $L_b \le L_p$ $\quad M_n = M_p$ ***AISC Equation F2-1***

For $L_p < L_b \le L_r$ $\quad M_n = C_b\left[M_p - \left(M_p - 0.7F_yS_x\right)\left(\frac{L_b - L_p}{L_r - L_p}\right)\right] \le M_p$

AISC Equation F2-2

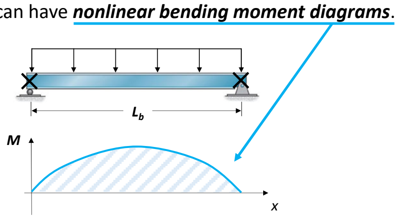
For $L_b > L_r$ $\quad M_n = F_{cr}S_x \le M_p$ ***AISC Equation F2-3***

$$F_{cr} = \frac{C_b\pi^2 E}{\left(L_b/r_{ts}\right)^2}\sqrt{1 + 0.078\frac{Jc}{S_xh_0}\left(\frac{L_b}{r_{ts}}\right)^2}$$ ***AISC Equation F2-4***

3

Chapter 5 – Compact Shapes

- The C_b coefficient is used in flexural expressions to account for the ***variation of bending moment*** along the length of a member.
- End-supported beams or braced segments, either due to their loading arrangement and/or support restraint condition, can have ***nonlinear bending moment diagrams***.



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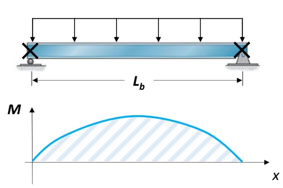
Chapter 5 – Compact Shapes

- The nominal flexural strength is ***conservative*** for beams with ***nonlinear moment diagrams***.
- The C_b coefficient is used to more accurately model the actual strength of the beams.



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Chapter 5 – Compact Shapes

- If there is a moment gradient, the value of C_b is given by:

$$C_b = \frac{12.5M_{max}}{2.5M_{max} + 3M_A + 4M_B + 3M_C}$$ ***AISC Equation F1-1***

where: M_{max} is the absolute value of the ***maximum moment*** within the unbraced length (including the end points of the unbraced length)

M_A is the absolute value of the moment at the ***quarter point*** of the unbraced length

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Chapter 5 – Compact Shapes

- If there is a moment gradient, the value of C_b is given by:

$$C_b = \frac{12.5M_{max}}{2.5M_{max} + 3M_A + 4M_B + 3M_C}$$ ***AISC Equation F1-1***

where: M_B is the absolute value of the moment at the ***midpoint*** of the unbraced length

M_C is the absolute value of the moment at the ***three-quarter point*** of the unbraced length

- ***AISC Equation F1-1*** is valid for doubly symmetric members and for singly symmetric members in single curvature.

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Chapter 5 – Compact Shapes

- If there is a moment gradient, the value of C_b is given by:

$$C_b = \frac{12.5M_{max}}{2.5M_{max} + 3M_A + 4M_B + 3M_C}$$ ***AISC Equation F1-1***

- When the bending moment is uniform, ***M***, the value of C_b is:

$$C_b = \frac{12.5M}{2.5M + 3M + 4M + 3M} = 1.0$$

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Chapter 5 – Compact Shapes

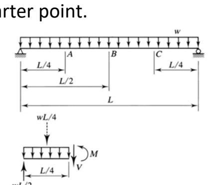
- **Example 5.5**: Determine C_b for a uniformly loaded, simply supported **W** shape with lateral support at its ends only.

Because of symmetry, the maximum moment is at midspan, so

$$M_{max} = M_B = \frac{wL^2}{8}$$ **AISC Table 3-22**

Also, due to symmetry, the moment at the quarter point equals the moment at the three-quarter point.

$$M_A = M_C = \frac{wL}{2}\left(\frac{L}{4}\right) - \frac{wL}{4}\left(\frac{1}{2}\right)\left(\frac{L}{4}\right) = \frac{3wL^2}{32}$$



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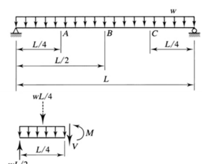
Chapter 5 – Compact Shapes

- **Example 5.5**: Determine C_b for a uniformly loaded, simply supported W shape with lateral support at its ends only.

$$C_b = \frac{12.5M_{max}}{2.5M_{max} + 3M_A + 4M_B + 3M_C}$$

$$= \frac{12.5(1/8)}{2.5(1/8) + 3(3/32) + 4(1/8) + 3(3/32)} = 1.136$$



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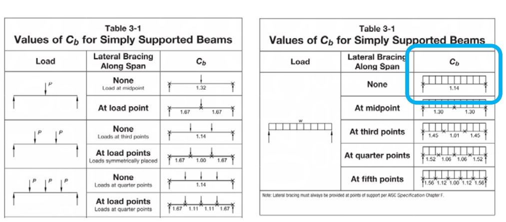
Chapter 5 – Compact Shapes

- Values of C_b are tabulated for many common cases of loading and lateral support.

- These values can be found in **Table 3-1** in **Part 3 of the Manual**, "Design of Flexural Members."



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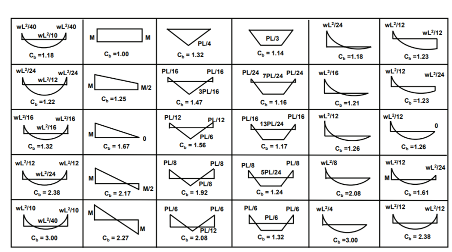
Chapter 5 – Compact Shapes

- Values of C_b are tabulated for many common cases of loading and lateral support.

- These values can be found in **Table 3-1** in **Part 3 of the Manual**, "Design of Flexural Members."



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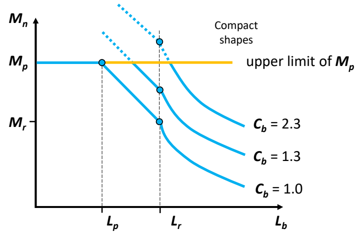
Chapter 5 – Compact Shapes

- The effect of C_b on the nominal strength is shown below.
- Although the strength is directly proportional to C_b, this graph clearly shows the importance of observing the upper limit of M_p, regardless of which equation is used for M_n.



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Chapter 5 – Compact Shapes

- **Part 3 of the Steel Construction Manual**, "Design of Flexural Members," contains several useful tables and charts for the analysis and design of beams.
- For example, **Table 3-2**, "W Shapes, Selection by Z_x," (hereafter referred to as the "Z_x table").
- The Z_x table lists shapes commonly used as beams, arranged in order of ***available flexural strength***— $\phi_b M_{px}$.

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Chapter 5 – Compact Shapes

F_y = 50 ksi Table 3-2 (continued) W-Shapes Z_x

F_y = 50 ksi

Table 3-2 (continued)
W-Shapes
Selection by Z_x

Z_x

increasing values of Z_x

Shape	Z_x	M_{px}/Ω_b	$\phi_b M_{px}$	M_{rx}/Ω_b	$\phi_b M_{rx}$	BF/Ω_b	$\phi_b BF$	L_p	L_r	I_x	V_{nx}/Ω_v	$\phi_v V_{nx}$
	in.^{3}	kip-ft	kip-ft	kip-ft	kip-ft	kips	kips	ft	ft	in.^{4}	kips	kips
		ASD	LRFD	ASD	LRFD	ASD	LRFD				ASD	LRFD
W21×55	**126**	**314**	**473**	**192**	**289**	**10.8**	**16.3**	**6.11**	**17.4**	**1140**	**156**	**234**
W14×74	126	314	473	196	294	5.31	8.05	8.76	31.0	795	128	192
W18×60	123	307	461	189	284	9.62	14.4	5.93	18.2	984	151	227
W12×79	119	297	446	187	281	3.78	5.67	10.8	39.9	662	117	175
W14×68	115	287	431	180	270	5.19	7.81	8.69	29.3	722	116	174
W10×88	113	282	424	172	259	2.62	3.94	9.29	51.2	534	131	196
W18×55	**112**	**279**	**420**	**172**	**258**	**9.15**	**13.8**	**5.90**	**17.6**	**890**	**141**	**212**
W21×50	**110**	**274**	**413**	**165**	**248**	**12.1**	**18.3**	**4.59**	**13.6**	**984**	**158**	**237**
W12×72	108	269	405	170	256	3.69	5.56	10.7	37.5	597	106	159
W21×48[f]	**107**	**265**	**398**	**162**	**244**	**9.89**	**14.8**	**6.09**	**16.5**	**959**	**144**	**216**
W16×57	105	262	394	161	242	7.98	12.0	5.65	18.3	758	141	212
W14×61	102	254	383	161	242	4.93	7.48	8.65	27.5	640	104	156
W18×50	101	252	379	155	233	8.76	13.2	5.83	16.9	800	128	192
W10×77	97.6	244	366	150	225	2.60	3.90	9.18	45.3	455	112	169
W12×65[f]	96.8	237	356	154	231	3.58	5.39	11.9	35.1	533	94.4	142

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Chapter 5 – Compact Shapes

- The Z_x table has tabulated values for L_p and L_r (which is particularly tedious to compute).
- Values for L_p and L_r can also be found in several other tables in **Part 3** of the Manual.
- We cover additional ***design aids*** in other sections of this chapter.

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Chapter 5 – Compact Shapes

Let's work on some problems

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Chapter 5 – Beams

Any questions?

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