Approximate Stiffness and Bending Strength for Compact-Rolled Sections

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On occasion, most of us have been caught in the predicament of needing to make a preliminary design and not having a copy of the AISC Manual available. Fortunately, there are three simple equations which give stiffness and bending strength values for compact-rolled sections of 36 ksi or 50 ksi yield steel beams having a braced compression flange. These equations give values which are accurate within 10% for the bold-face sections in the AISC Manual's Allowable Stress Design Selection Table.

The normal equation for moment of inertia of a plane section is:

$$I = KAD^2$$

K = Shape factor

A = Cross-sectional area of section

D = Depth of section

If all rolled sections had the same shape factor, we could substitute the beam weight per foot for the area and write an equation:

$$I_{xx} = (K/3.4)(W)(D)^2$$

K = Shape factor

W = Beam weight in pounds per foot

D = Normal depth of beam in inches

They do not, and this approach does not work.

It seems possible we might be able to allow for the change in shape factor by including the weight as a product with the depth and changing the power of the product from 2 to N. The equation then becomes:

$$I_{xx} = (K)(WD)^N$$

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If we compare the properties of two different rolled sections:

$$\frac{I_{xx1}}{I_{xx2}} = \frac{(K)(W_1D_1)^N}{(K)(W_2D_2)^N} = \frac{(W_1D_1)^N}{(W_2D_2)^N}$$

$$N = \frac{\text{Log }(I_{xx1}/I_{xx2})}{\text{Log }(W_1D_1/W_2D_2)}$$

Obviously, once N is known, we can solve directly for K.

If we use this calculation to solve for N and K of adjoining bold-face values in the Design Strength Table and compare the values statistically, we find the following formula will give values for major axis moments of inertia in units of inches^4 which are within 10% of the tabulated values for all of the sections except for W6×9 and for the two heaviest shapes.

$$I = (3/32)(WD)^{4/3}$$

The equations for allowable bending moment are equally simple and equally accurate for compact sections rolled of 36 ksi or 50 ksi steel.

With 36 ksi steel:

$$M_R\text{ (kip-ft)} = \frac{(3/32)(WD)^{4/3}(24)}{(12)(D/2)} = \frac{(3/8)(WD)^{4/3}}{D}$$

With 50 ksi steel:

$$M_R\text{ (kip-ft)} = \frac{(3/32)(WD)^{4/3}\,(33)}{(12)(D/2)} \approx \frac{(WD)^{4/3}}{2D}$$

As Table 1 shows, these equations work for preliminary design of each of the most weight efficient sections except for the three exceptions mentioned earlier.

Table 1

Size	I_{xx} in.^{4} Table	I_{xx} in.^{4} Calc.	% Error	F_y = 50 ksi M_r Table kip-ft	M_r Calc. kip-ft	% Error	F_y = 36 ksi M_r Table kip-ft	M_r Calc. kip-ft	% Error
M6×4.4	7.2	7.4	2.8	7	7	0	5	5	0
M8×6.5	18.5	18.2	1.6	13	12	7.7	9	9	0
W6×9	16.4	19.1	16	15	17	13	11	13	18
M10×9	38.8	37.8	2.6	21	20	4.8	16	15	6.3
W8×10	30.8	32.3	4.9	21	21	0	16	16	0
W12×11.8	71.9	69.2	3.8	33	31	6.1	24	23	4.2
W12×14	88.6	86.9	1.9	41	39	4.9	30	29	3.3
W12×16	103	104	1.0	47	46	2.1	34	35	2.9
M14×18	148	149	0.7	58	57	1.7	42	43	2.4
W12×19	130	131	0.8	59	58	1.7	43	43.5	1.2
W10×22	118	125	5.6	64	66	3.1	46	50	8.7
W12×22	156	159	1.9	70	71	1.4	51	53	3.9
W14×22	199	195	2.0	80	74	7.5	58	56	3.4
W12×26	204	198	2.9	92	88	4.3	67	66	1.5
W14×26	245	244	0.4	97	93	4.1	71	70	1.4
W16×26	301	291	3.3	106	97	8.5	77	73	5.2
W12×30	238	240	0.8	106	107	0.9	77	80	3.9
W14×30	291	295	1.4	116	112	3.4	84	84	0
W16×31	375	368	1.9	130	123	5.4	94	92	2.1
W14×34	340	348	2.4	134	133	0.7	97	100	3.1
W18×35	510	506	0.8	158	150	5.1	115	113	1.7
W16×40	518	517	0.2	178	172	3.4	129	129	0
W18×40	612	605	1.1	188	179	4.8	137	134	2.2
W21×44	843	844	0.1	224	214	4.5	163	161	1.2
W18×50	800	815	1.9	244	241	1.2	178	181	1.7
W21×50	984	1,001	1.7	260	254	2.3	189	191	1.1
W18×55	890	925	3.9	270	274	1.5	197	206	4.6
W24×55	1,350	1,357	0.5	314	302	3.8	228	226	0.9
W21×62	1,330	1,333	0.2	349	339	2.9	254	254	0
W24×62	1,550	1,593	2.8	360	354	1.7	262	265	1.1
W21×68	1,480	1,508	1.9	385	383	0.5	280	287	2.5
W24×68	1,830	1,801	1.6	424	400	5.7	308	300	2.6
W24×76	2,100	2,089	0.5	484	464	4.1	352	348	1.1
W24×84	2,370	2,388	0.8	539	531	1.5	392	398	1.5
W27×84	2,850	2,794	2.0	586	552	5.8	426	414	2.8
W24×94	2,700	2,774	2.7	611	616	0.8	444	462	4.1
W27×94	3,270	3,246	0.7	668	641	4.0	486	481	1.0
W30×99	3,990	4,002	0.3	740	712	3.8	538	534	0.7
W30×108	4,470	4,495	0.6	822	799	2.9	598	599	0.2
W30×116	4,930	4,944	0.3	905	879	2.9	658	659	0.2
W33×118	5,900	5,743	2.7	987	928	6.0	718	696	3.1
W33×130	6,710	6,535	2.6	1,120	1,060	5.4	812	792	2.5
W36×135	7,800	7,720	1.0	1,210	1,140	5.8	878	858	2.3
W33×141	7,450	7,280	2.3	1,230	1,180	4.1	896	883	1.5
W36×150	9,040	8,880	1.8	1,390	1,320	5.0	1,010	987	2.3
W36×160	9,750	9,680	0.7	1,490	1,430	4.0	1,080	1,080	0
W36×170	10,500	10,490	0.1	1,600	1,555	2.8	1,160	1,170	0.9
W36×182	11,300	11,490	1.7	1,710	1,700	0.6	1,250	1,280	2.4
W36×194	12,100	12,520	3.5	1,830	1,850	1.1	1,330	1,390	4.5
W33×201	11,500	11,680	1.6	1,880	1,890	0.5	1,370	1,420	3.6
W36×210	13,200	13,910	5.4	1,980	2,060	4.0	1,440	1,550	7.6
W33×221	12,800	13,260	3.6	2,080	2,140	2.9	1,510	1,610	6.6
W36×230	15,000	15,700	4.7	2,300	2,330	1.3	1,670	1,745	4.5
W36×245	16,100	17,080	6.1	2,460	2,530	2.8	1,790	1,900	6.1
W36×260	17,300	18,490	6.9	2,620	2,740	4.6	1,900	2,055	7.6
W36×280	18,900	20,410	8.0	2,830	3,025	6.9	2,060	2,270	10.2
W36×300	20,300	22,380	10.2	3,050	3,315	8.7	2,220	2,490	12.2