ESTIMATING THE AXIAL CAPACITY OF COMPRESSION MEMBERS

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Are you still writing equations on the back of envelopes? Try this timesaving design aid for estimating the axial capacities of commonly-used compression members.

Computers can be used to perform complex calculations at incredible speeds. Complicated design equations that would take pages and hours to complete can be plugged into a spreadsheet that yields immediate results. In spite of myriad technological advancements, there is still a need for "quick and dirty" design methods. After all, isn't that what the back of the envelope was made for? This practical design aid will provide reasonable estimates for axial capacities of common compression members. You won't need a computer. And you may not even need your trusty envelope!

When calculating compressive strength using the AISC *LRFD Specification*, a multitude of variables, equations, and reduction factors must be considered. In some cases, flexural buckling controls, and the only consideration is whether λ_c is greater or less than 1.5. However, with non-symmetric shapes flexural-torsional buckling and its related critical buckling stress F_{crft} must be considered. In other cases, the effects of local buckling need to be determined through the use of reduction term Q. Each of these calculations takes a significant amount of time and requires a solid understanding of which equations to use.

The rules of thumb presented here use simple variables. For each calculation, you will need to know the nominal weight per linear foot (Wt), the effective length of the compression member in feet (KL), and one critical dimension of the section (b_f, d, or h).

The presented equations serve as quick, reasonably accurate estimates of the capacity of several different types of compression members. Due to large local buckling reduction factors for tees and rectangular hollow structural sections (HSS), rules of thumb were not developed for these shapes. For the shapes that are presented, the rules of thumb were developed to apply to those sizes found in the column tables in the 3rd Edition *LRFD Manual*.

Each equation is derived from a linear approximation of the standard LRFD column curves and an approximate gross area. The linear approximation is generally within 15% of the actual design strength (for $KL/r \leq 180$), although this is not always conservative. Unconservative cases are discussed in the box on the next page. The equations do apply for slenderness ratios greater than 180, but the approximations tend to become less accurate.

The table also includes equations that approximate the area of steel sections using the nominal weight per foot (based on a standard steel weight of 490 lb/ft^3). These equations take into consideration a 0.93t design thickness for hollow structural sections. Also included are approximate Wt values for those shapes not generally specified with the Wt values (such as angles, for which weight does not appear in the designation like L8×8×½). Finally, the table includes approximate r values for use in quickly approximating slenderness ratios.

This work was inspired by a 2001 NASCC conference paper, "Rules of Thumb for Steel Design," by John Ruddy, Chief Operating Officer and Principal, Structural Affiliates International, Nashville.

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Shape	F_y	Approx. A	Approx. Wt	Approx. r	Approx. F_{cr}
W	50	$\frac{Wt}{3.4}$	N/A	$r_y \approx 0.22 b_f$	$50 - 12\frac{KL}{b_f}$
HP	36	$\frac{Wt}{3.4}$	N/A	$r_y \approx 0.24 d$	$36 - 8\frac{KL}{b_f}$
Equal leg L	36	$\frac{Wt}{3.4}$	$6.5bt$	$r_z \approx 0.20 b$	$36 - 10\frac{KL}{b}$
Equal leg 2L, 3/8″ separation	36	$\frac{Wt}{3.4}$	$13bt$	$r_y \approx 0.20 b$	$36 - 6.5\frac{KL}{b}$
Square HSS	46	$\frac{Wt}{3.65}$	$12ht$	$r \approx 0.37 h$	$46 - 7\frac{KL}{h}$
Round HSS	42	$\frac{Wt}{3.65}$	$10dt$	$r \approx 0.33 d$	$42 - 7\frac{KL}{d}$
Pipe	35	$\frac{Wt}{3.4}$	$10dt$	$r \approx 0.32 d$	$35 - 5.5\frac{KL}{d}$

A	area
b	leg length, in.
b_f	flange width, in.
d	depth of member (HP); outer diameter of member (Round HSS and Pipe), in.
h	outer dimension of square HSS, in.
r, r_y, r_z	radius of gyration, in.
KL	effective length, ft
t	thickness
Wt	weight of member, lb/ft

THE FINE PRINT

Final designs must always be verified to comply with the requirements in the *LRFD Specification*. Here's why:

The linear approximation of the axial design strength curve is illustrated in the graph. In the case of each shape, the equations approximate a value that is conservative for smaller values of KL/r. As the effective length increases, the approximation results become higher than the actual capacity (although it generally stays within 15%), and then turn back toward conservative as KL/r increases further up to the slenderness limit of $KL/r = 180$.

There are some particular problem cases that should be noted:

- **Square HSS.** The approximation for axial capacity is higher (as much as 50%) than the actual value for some thick walled sections when $120 < (KL/r) < 150$ and is lower (as much as 20%) than the actual value for many sections when $30 < (KL/r) < 90$.
- **W-Shapes.** The approximation for axial capacity is higher (as much as 30%) than the actual value for the lightest sections for each nominal depth when 19 ft < KL < 28 ft.
- **Double Angles.** The approximation for axial capacity is higher (as much as 25%) than the actual value for thick-legged sections when $140 < (KL/r) < 170$.