

Column & Panel Buckling Cheat Sheet

Euler, Johnson and plate buckling formulas

ENGINEERING
CHEAT SHEET

Key equations

Quantity	Equation	Notes
Euler critical load	$P_{cr} = \pi^2 E I / (K L)^2$	Long, slender columns only. Use the smallest I
Critical stress	$\sigma_{cr} = \pi^2 E / (K L / r)^2$	r = radius of gyration
Radius of gyration	$r = \sqrt{I / A}$	A = cross-section area
Slenderness ratio	$K L / r$	Higher = more prone to buckling
Transition value	$C_c = \sqrt{(2 \pi^2 E / \sigma_y)}$	Long column if $K L / r > C_c$
Johnson (intermediate)	$\sigma_{cr} = \sigma_y - (\sigma_y^2 / 4\pi^2 E)(K L / r)^2$	Use when $K L / r < C_c$. Short columns crush at σ_y
Plate buckling	$\sigma_{cr} = k \pi^2 E / [12(1 - \nu^2)] \cdot (t / b)^2$	k = buckling coefficient, t = thickness, b = unsupported width

Key takeaways

- Buckling is governed by **stiffness and geometry**, not strength. A column can buckle well below yield.
- Halving a panel's unsupported width or doubling its thickness raises its critical stress about **4x**, because σ_{cr} scales with $(t/b)^2$.
- Stiffening beads, ribs and flanges are the lightweight fix for sheet metal panels. Confirm with FEA.
- If elastic buckling governs, a stronger steel does not help (E stays the same). Use a better shape or a stiffer material.
- A column loses capacity after buckling. A plate can carry more load after it buckles (design with effective width).
- Worked example: 40 × 40 mm steel column, 1.5 m, $E = 200$ GPa. Pinned-pinned: $P_{cr} = \mathbf{187.2 \text{ kN}}$ (Euler). Fixed-fixed (Johnson): 346.6 kN, only 1.85x gain, not 4x.
- Always apply a safety factor and check local buckling, eccentric loads and the governing code (AISC, Eurocode).

Effective length factor K and plate k

Case	Theoretical K / k	Notes
Pinned - pinned	$K = 1.0$	Baseline (1x)
Fixed - fixed	$K = 0.5$ (design 0.65)	Up to 4x in theory
Fixed - pinned	$K = 0.7$ (design 0.80)	About 2x
Fixed - free	$K = 2.0$ (design 2.1)	One quarter
Plate, both long edges simply supported	$k = 4.00$	Clamped edges: 6.97