GATE PATHSHALA

Buckling of Columns — Formula Sheet

Author Name: Krishna Teja

April 9, 2025

1. Euler's Buckling Load (Ideal Pin-Ended Column)

$$P_{\text{cr}} = \frac{\pi^2 EI}{(L_{\text{eff}})^2}$$

- P_{cr}: Critical (buckling) load
- E: Young's modulus of elasticity
- I: Least moment of inertia of cross-section
- L_{eff}: Effective length of the column

2. Effective Length for Different End Conditions

End Condition	Effective Length L_{eff}
Both ends pinned	L
Both ends fixed	$\frac{L}{2}$
One end fixed, one end free	$2L$
One end fixed, one end pinned	$\frac{L}{\sqrt{2}}$

3. Slenderness Ratio

$$\lambda = \frac{L_{\text{eff}}}{r}, \quad \text{where} \quad r = \sqrt{\frac{I}{A}}$$

- λ: Slenderness ratio
- r: Radius of gyration
- A: Cross-sectional area

4. Column Classification

- **Short column**: Fails by yielding (compression failure)
- **Long column**: Fails by buckling (Euler's load governs)

5. Critical Stress (Euler Form)

$$\sigma_{\text{cr}} = \frac{P_{\text{cr}}}{A} = \frac{\pi^2 E}{\left(\frac{L_{\text{eff}}}{r}\right)^2}$$

6. Johnson's Parabolic Formula (Inelastic Buckling)

$$\sigma_{\text{cr}} = \sigma_y \left[1 - \frac{\sigma_y}{4\pi^2 E}\left(\frac{L_{\text{eff}}}{r}\right)^2\right]$$

(Applicable to intermediate columns)

7. General Behavior

Behavior	Condition
Elastic buckling (Euler)	High slenderness ratio, long column
Inelastic buckling	Intermediate slenderness
Crushing failure	Low slenderness ratio, short column