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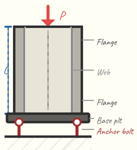

Steel Column Design

BS 5950 · DM Dubai · End Conditions · Slenderness · Failure Modes · Strengthening

DM Examination — G+1 & G+4 Steel Construction

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Column Key Facts

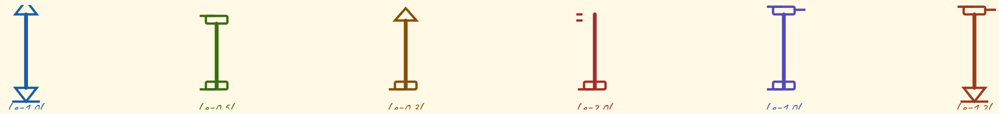
- E = 205,000 MPa (steel)
- γ = 78.5 kN/m³ (unit weight)
- λ max = 180 (BS 5950)
- py (S275) = 275 MPa
- py (S355) = 355 MPa
- Strut curve b → UC minor axis

What is a Steel Column? (Basics)

- Primary compression member — load acts along longitudinal axis
- Also called stanchion (building), strut (truss), post (frame)
- Short column → Squash/yield governs (low λ)
- Slender column → Buckling governs (high λ)

UC / I-Section	RHS / SHS	CHS	Angle / UPN	H / HD / HEA
British std	Hollow section	Circular hollow	UPN = Channel	German std
UB254×126×37	100×100×7 SHS	Best torsion resist	Bracing use	HEA380 (d=380mm)

End Conditions & ky Values (Key) DM EXAM



Pin-Pin	Fix-Fix	Fix-Pin	Fix-Free	FF-Sway	FP-Sway
ky=1.0	ky=0.5	ky=0.7	ky=2.0	ky=1.0–1.5	ky=1.2

Fix=0.5 · Pin-Pin=1.0 · Cantilever=2.0 · Sway always increases ky!

Slenderness Ratio (λ) (Concept)

$\lambda = L_e / r$

Meaning: How "slim" the column is vs its buckling resistance. Tall thin = high λ. Short fat = low λ.

- λ < 30 — Stocky. Squash/yield. P = Ag×py
- 30–120 — Inelastic buckling. Perry-Robertson
- λ > 120 — Elastic buckling. Euler governs. Low capacity!

Significance: Determines which failure mode, which formula, and which strut curve (a/b/c/d) to use in BS 5950 design.

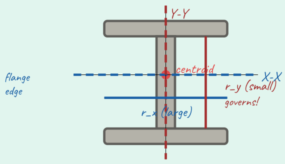
BS 5950: λ ≤ 180 max · Sweet spot: λ = 50–90 for efficiency

DM: ky(sway)=1.5 · ky(cantilever)=2.0 · Laced struts: lx = ly

Radius of Gyration (r) (Concept)

$r = \sqrt{(I / A)}$

Meaning: How far the section's area is spread from its centroid. Larger r = more resistance to buckling.



- UC: r_y << r_x — weak Y-Y axis always governs
- CHS: r_x = r_y — equal all directions, best for compression
- RHS/SHS: near-equal r — good compression choice
- Laced struts: design so lx = ly (equal buckling each way)

Always use r_min (Y-Y axis for UC) to get λ_max for design

Euler Theory (Theory)

$P_e = \pi^2 EI / L_e^2$ $\sigma_e = \pi^2 E / \lambda^2$

- Valid: perfectly elastic, pin-ended, straight
- Ignores imperfections & residual stress
- Only accurate for very slender (high λ)
- E = 205,000 MPa for steel

Real columns fail earlier than Euler! Perry-Robertson corrects this.

Short vs Slender Column (Compare)

Short Column
Yields first
P = Ag × py

Slender Column
Buckles first
P = Pe (Euler)

Perry-Robertson (BS 5950)

$\eta = a(\lambda - \lambda_0)/1000$ $\lambda_0 = 0.2\sqrt{(\pi^2 E/py)}$

- η = Perry imperfection factor
- a = Robertson constant (from strut curve)
- η=0 → perfect Euler column (impossible!)
- η↑ → more imperfection → less capacity
- Real pc always less than Euler

Think: η = column's ugliness factor!"

Euler to Design — Logic Path (Flow)

Geometry L section → Effective Length Le → Slenderness λ = Le/r → Euler Fe = π²E/λ² → Perry η imperfection → Get pc strut table → Pc=Agxpc BS 5950 → Pc≥P? Pass/Fail

BS 5950 — Steel Column Design (UAE Primary Code) (BS Code)

Compressive Resistance:

$P_c = A_g \times p_c$

p_c = design compressive stress from strut tables based on λ and py (N/mm²)

Section Classification:

Class 1 Plastic | Class 2 Compact | Class 3 Semi | Class 4 Slender

Strut Curves:

Curve	Section type	a
a	UC major axis	2.0
b	UC minor ← use	3.5
c	Welded sections	5.5
d	Hollow/thick	8.0

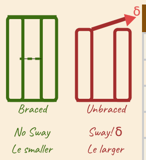
"b is Best everyday choice!"

Steel Grades: DM EXAM

Grade	t≤16mm	t=63mm
Gr43/S275	275	255
Gr50/S355	355	335
Grade 55	450	430
Grade 63	420	400
A36 (AISC)	250	250

Check: $P_c \geq P$ applied · λ ≤ 180

Sway Limits — Full Detail (Sway) DM EXAM



Condition	Limit
General frame sway	H/200
Frame + brick wall	H/200
Sensitive cladding	H/300
Beam DL+LL	L/200
Beam LL only	L/360
Roof LL (non-plaster)	L/200
Crane girder (wind)	L/500

Braced (No-Sway)

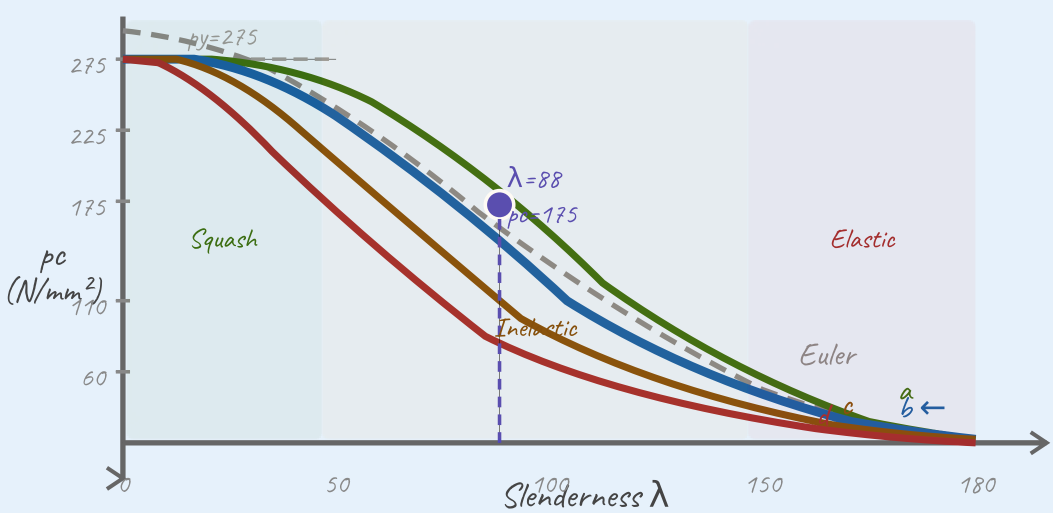
- Lateral loads by bracing/core
- ky = 0.5–1.0 · Lower Le
- More economical columns

Unbraced (Sway)

- Columns resist lateral loads
- ky = 1.0–2.0 · Larger Le
- Heavier section required

DM rule: δ/h ≤ 1/200 for no-sway assumption. If exceeded → sway frame method + amplified moment factor kr

Column Curve — pc vs λ (BS 5950) (Graph)



Curve b is default for UC columns about minor axis. Lower curve = more imperfection = less capacity.

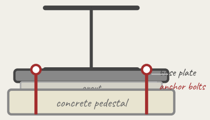
DM Code — G+1 & G+4 (DM) EXAM

- Basis: BS 5950 + Eurocode 3

- Weld code: AWS D1.1
- Min bolt edge dist: 1.5D
- Wind gust: 45 m/s / 3 sec
- Sway limit: H/200 G+1/G+4
- Cantilever ky = 2.0
- Sway frame ky = 1.0–1.5
- Min PEB plate: 6 mm
- CE marking + mill certs required
- NOC + 3rd party inspection
- Hot-dip galvanizing (exposed)

⚠ Always check latest DM circular!

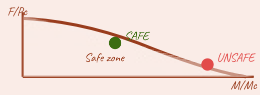
Base Plate Design (Basics)



- Distributes column load to foundation
- Area: $A = P / f_c$ (bearing stress)
- Thickness: $t = \sqrt{(3w/py)} \times c$
- Anchor bolts resist uplift + shear
- Always include grout layer 25–50mm

Combined Axial + Moment (Interaction)

F/Pc + M/Mcx ≤ 1.0



- Columns rarely carry pure axial load
- Eccentric load, wind → add moment M
- Check: F/Pc + M/Mcx ≤ 1.0
- Point inside curve = SAFE

Modes of Failure (Failure)

Flexural Buckling
Weak axis bending. Most common. High λ.

Torsional Buckling
Twists longitudinally. Open sections.

Local Buckling
Flange/web buckles. Class 3/4.

Squashing
Short column, low λ. Yields first.

Flexural-Torsional
Bends + twists. Asymmetric sections.

Lateral-Torsional
With moment. Flange buckles laterally.

"Fairly Few Turtles Locally Squash Limes" – Flexural·F-T·Torsional·Local·Squash·LT

Strengthening Options (Fix)

↔
Reduce Le
Add bracing. Best value!

+
Stiffeners
Prevent local buckle

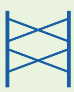
█
Cover Plates
Weld to flanges

▲
Upsize Section
Heavier UC/HD

■■
Fix Ends
Pinned→fixed: Le halves!

∞
Built-up/CFRP
Heavy loads

Laced vs Battened Column: DM EXAM



Laced Column
Diagonal lacing bars
Design: Ix = Iy

Battened Column
Horizontal batten plates
Spacing controlled

Cheapest fix: Fix ends → Brace → Stiffen → Cover plates → New section

Worked Problem – BS 5950 Column Design (Example)

Given: P = 45 kN · L = 3.5 m · Both ends pinned · Grade S275 · Try 100×100×7 SHS · Ag = 2640 mm^2 · r = 39.6 mm

1

Effective Length

Both pinned → ky = 1.0

Le = 1.0 × 3500

Le = 3500 mm

2

Slenderness Ratio

λ = Le/r = 3500/39.6

λ = 88.4 < 180 ✓

3

Euler Fe

Fe = π^2×205000/88.4^2

Fe = 258 MPa

BS

BS 5950 Strut b

pc ≈ 175 N/mm^2

Pc = 2640 × 175

Pc = 462 kN

462≥45 PASS

DM

DM Code Check

DM = BS 5950 basis

Same Pc applies

Pc = 462 kN

462≥45 PASS

!

Observation

Utilisation = 10%

Over-designed!

Try 50×50 SHS ↓

✓ 100×100×7 SHS (S275) PASSES BS 5950 & DM for 45 kN – utilisation only 10%, could downsize!

DM Exam MCQ (G+1 G+4)

1. Yield strength Grade 43, t≤16mm?
a) 250b) 355c) 275d) 420
✓ Answer: c) 275 N/mm^2

2. ky value for cantilever column?
a) 0.5b) 1.0c) 1.5d) 2.0
✓ Answer: d) 2.0

3. Allowable sway limit (general frame)?
a) H/100b) H/200c) H/300d) H/500
✓ Answer: b) H/200

4. Laced struts designed for?
a) lx>lyb) lx=lyc) lx<lyd) lx=0
✓ Answer: b) lx = ly

5. Crane girder deflection (wind)?
a) L/200b) L/360c) L/500d) L/240
✓ Answer: c) L/500

Common Mistakes (Watch Out!)

Using r_x instead of r_y for UC
Always use r_min (weak axis) → gives λ_max → governs design

Wrong ky for sway frame
Sway frames: ky=1.0–2.0, not 0.5–0.7. Always check braced vs unbraced!

Ignoring sway in G+4 frames
Multi-storey unbraced frames: check sway at EVERY storey, not just top

Using wrong strut curve
Default for UC minor axis = curve b. Welded sections = curve c. Not interchangeable!

Forgetting DM local requirements
CE marking, mill certs, NOC, 3rd party check – all mandatory in Dubai projects

Quick Reference (Summary)

Key Formulas

λ=Le/r · r=√(I/A) | Pe=π^2EI/Le^2 | Pc=Ag×pc

ky Values

Condition	ky
Fix-Fix	0.5
Fix-Pin	0.7
Pin-Pin	1.0
FF-Sway	1.0–1.5
Cantilever	2.0

Sway Limits

Condition	Limit
General sway	H/200
Beam LL only	L/360
Crane girder	L/500

Key Numbers

γ=78.5kN/m^3 · E=205,000MPa · λ_{max}=180 · AWS D1.1 · Min bolt edge=1.5D