# EXPERT DESIGN OF A DOUBLE-T COLUMN BASE CONNECTION

## RIGID BASE PLATE + ANCHOR BOLTS UNDER EUROCODE – PLASTIC (LOWER BOUND) APPROACH

### 1. STRUCTURAL IDEALISATION AND PLASTIC MODEL

Rigid base plate model (EN 1993-1-8 §6.2.8)

**PLASTIC ASSUMPTION (LOWER BOUND)**

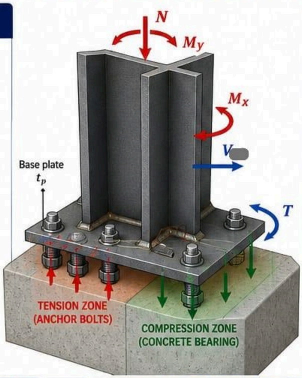
Allow any statically admissible stress field that does not violate material strength.

**TENSION ZONE ($N + M$)**

All tensile forces are resisted exclusively by anchor bolts. Plastic redistribution assumed: bolts at extreme edge form an equivalent tension row → maximise lever arm and moment capacity.

**COMPRESSION ZONE ($N + M$)**

Compression transferred by direct bearing between base plate and concrete (compression T-stub analogy). Only area under flanges and web is effective. No frictional adhesion is assumed (non-slip mechanism).




**DESIGN BEARING STRENGTH OF CONCRETE**

$$F_{jd} = \beta_j \cdot \alpha \cdot \frac{\alpha_{cc} f_{ck}}{\gamma_c}$$

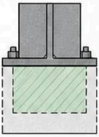
where:

$\beta_j = \frac{2}{3}$ (recommended)

$\alpha_{cc} \approx 1.0$

$\gamma_c = 1.5$

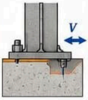
$\alpha = \sqrt{\frac{A_{c1}}{A_{c0}}} \leq 3.0$ ($\leq 3.0$)



$A_{c1}$ = effective loaded area (under flanges + web)

$A_{c0}$ = reference area $= b_p \times l_p$

### 2. LOAD TRANSFER MECHANISMS

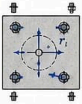



**SHEAR $V$**

Transferred through a hierarchy of mechanisms:

1. Friction: $V_{ff} = C_{f,d} \cdot N_{c,min}$ ($C_{f,d} \approx 0.20$ for mortar)
2. Anchor bolts in shear
3. Shear key (recommended for high shear / fatigue)

Only the minimum compressive force contributes to friction – this is often overestimated in practice.




**TORSION $T$**

Resolved as plastic shear distribution in the bolt group:

$$V_{i,Ed} = \frac{T_{Ed}\, r_i}{\sum r_i^2}$$

Outer bolts reach shear resistance first; inner bolts equilibrate rotation – this is a fully plastic torsional mechanism, not elastic.

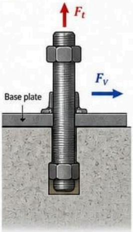
### 3. ANCHOR BOLT VERIFICATION

**a) STEEL RESISTANCE (EN 1993-1-8 + EN 1992-4)**

- Tension: $F_{t,Rd} = k_2 \frac{f_{ub} A_s}{\gamma_{M2}}$
- Shear: depends on thread position relative to shear plane
- Interaction (linear):

$$\frac{F_{v,Ed}}{F_{v,Rd}} + \frac{F_{t,Ed}}{1.4\, F_{t,Rd}} \leq 1.0$$

This linear interaction is conservative and aligned with ductile steel behaviour.




**b) CONCRETE RESISTANCE (EN 1992-4)**

Critical failure modes:

- Concrete cone breakout (tension & shear)
- Pull-out / pull-through
- Edge failure mechanisms

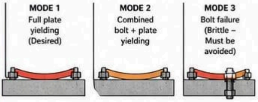
Interaction (elliptical):

$$\left(\frac{N_{Ed}}{N_{Rd}}\right)^{1.5} + \left(\frac{V_{Ed}}{V_{Rd}}\right)^{1.5} \leq 1.0$$

This reflects the nonlinear brittle nature of concrete, in contrast to steel.

### 4. BASE PLATE DESIGN – ENSURING PLASTIC REDISTRIBUTION

The base plate must behave as a ductile plastic component, enabling force redistribution. Design via T-stub analogy (EN 1993-1-8 §6.2.4):




Thickness $t_p$ is selected to force Mode 1 or 2, never Mode 3.

### 5. WELD VERIFICATION (PROFILE → PLATE)

Fillet welds are checked under combined stresses:

$$\sqrt{\sigma_\perp^2 + 3(\tau_\perp{}^2 + \tau_\parallel{}^2)} \leq \frac{f_u}{\beta_w \gamma_{M2}}$$

Key nuance: Welds transmit normal + transverse shear, not just longitudinal shear – this is often oversimplified in practice.

### 6. PLASTIC DESIGN ALGORITHM (OPERATIONAL SEQUENCE)

1. Define geometry: section, plate, bolt layout, materials
2. Assume compression footprint under flanges + web
3. Compute compression resultant and lever arm
4. Assign tensile force to extreme bolt row (plastic assumption)
5. Compute bolt forces:
   - Tension = $T_{Ed} / n_b$
   - Shear = $V_{Ed} / n_b$ + torsional component
6. Verify bolts: steel + concrete (dual check mandatory)
7. Design base plate via T-stub → enforce ductility
8. Check concrete bearing capacity
9. Verify welds

### 7. GOVERNING PHILOSOPHY

Steel → ductile, redistributes

Concrete → brittle, must be protected

Geometry → defines lever arm (the real source of strength)

### 8. SUMMARY OF VERIFICATIONS

| Component | Check Type | Code Reference | Governing Failure Mode |
|---|---|---|---|
| Anchor bolts | Tension, shear, interaction | EN 1993-1-8 §3.6<br>EN 1992-4 | Bolt steel yield, shear; Concrete breakout/pull-out |
| Concrete | Breakout, pull-out, shear | EN 1992-4 §7.2 | Concrete cone breakout, pull-out, edge failure |
| Base plate | T-stub bending (Modes 1–3) | EN 1993-1-8 §6.2.4 | Plate yielding or bolt failure |
| Concrete bearing | Compression under plate | EN 1993-1-8 §6.2.5 | Concrete crushing |
| Welds | Combined stress | EN 1993-1-8 §4.5.3 | Weld failure (normal/shear) |

### CLOSING INSIGHT

A rigid base is a small battlefield where three materials negotiate:

- Steel wants to yield
- Concrete wants to crack
- Bolts decide who wins

Design is the art of deciding that outcome before the structure does.