IMAGE TO CALCULATION

Concrete corbel
Strut-and-tie forces

Read a labelled corbel sketch, calculate the tie and compression-strut forces, and compare the resulting stress demands with explicitly adopted demonstration limits.

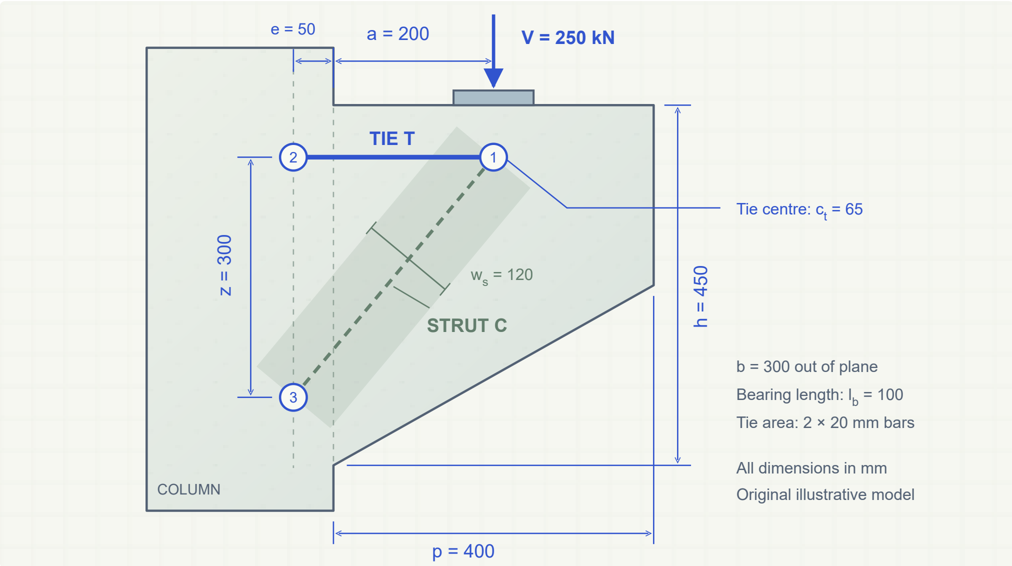

Figure 1. Original side elevation and assumed local load path for CB-01. The line model identifies node centres; it does not detail concrete nodal zones or reinforcement anchorage. Dimensions govern the sketch.

1. Reference inputs

Input group	Adopted reference values
Applied action	V = 250 kN downward; applied design-action input; no horizontal action
Concrete envelope	b = 300 mm out of plane; h = 450 mm at face; projection p = 400 mm
Bearing	a = 200 mm from column face to load line; contact length l_b = 100 mm; contact width = b
Node geometry	e = 50 mm inside column face; z = 300 mm; tie centroid c_t = 65 mm below top
Assumed effective areas	Two 20 mm tie bars; strut width w_s = 120 mm normal to its axis
Demonstration stress limits	Tie: 400 MPa · strut: 10 MPa · bearing face: 12 MPa

> **Original fictional example.** Loads, dimensions, effective strut width and stress limits are selected exercise inputs. The limits are not derived from a material grade or a design standard. Individual PASS labels below are comparisons with those assumptions, not approval of the corbel.

2. Calculate the forces from the node geometry.

The tie is horizontal between nodes 1 and 2. The compression strut joins nodes 3 and 1. Nodes 2 and 3 transfer the local actions into the supporting column. Moving the vertical bearing force down its same line of action to node 1 preserves equilibrium.

The distinction between concrete struts, reinforcement ties and their connecting nodes follows the general modelling framework in the FHWA STM manual, glossary, printed pages iii–iv. The geometry, derivation and numerical example here are original.

Node spacing and angle (1)

$$\ell = a + e, \qquad \theta = \tan^{-1}\left(\frac{z}{\ell}\right)$$

θ is the angle above horizontal; use consistent length units.

Tie and compression forces (2)

$$T = \frac{V\ell}{z}, \qquad C = \frac{V}{\sin\theta}$$

Both are positive magnitudes. At node 1: C sin θ = V and C cos θ = T.

Tie steel area (3)

$$A_s = n_b\frac{\pi d_b^2}{4}, \qquad A_{s,\text{lim}} = \frac{1000T}{f_{t,\text{lim}}}$$

A_s,lim is the tie area needed to meet the adopted comparison stress, not a complete reinforcement design.

Tie and nominal strut stress (4)

$$\sigma_t = \frac{1000T}{A_s}, \qquad \sigma_s = \frac{1000C}{bw_s}$$

kN × 1,000 / mm² gives MPa. w_s is assumed normal to the strut, not inferred from the drawing.

Bearing-face average stress (5)

$$\sigma_b = \frac{1000V}{bl_b}$$

Average vertical contact stress only; this does not check every nodal face.

Individual comparisons (6)

$$u_t = \frac{\sigma_t}{f_{t,\text{lim}}}, \quad u_s = \frac{\sigma_s}{f_{s,\text{lim}}}, \quad u_b = \frac{\sigma_b}{f_{b,\text{lim}}}$$

For each adopted limit: PASS if u ≤ 1, otherwise FAIL. Never combine these into an overall corbel pass.

Equilibrium check: use the correct reference plane

$$Tz = V(a+e) \quad \text{at the node plane;} \qquad M_{\text{face}} = Va$$

The node plane is e inside the column. Tz is not the moment at the column face. The force transferred at each end of the tie is T; its anchorage resistance is not calculated here.

> **Adopted geometry is an input.** z is the vertical node-centre spacing, not the overall depth h. c_t is the tie-centroid offset, not nominal cover. A change to effective strut width requires a newly justified compression-field and node geometry.

3. Work through one bearing position.

Use the dimensions from the image and the adopted inputs on page 1.

01 Resolve the geometry

$$\ell = 200 + 50 = 250\ \text{mm}, \qquad \theta = \tan^{-1}(300/250) = 50.19^\circ$$

The diagonal uses the distance from the lower column node to the loaded node.

02 Resolve the tie and strut forces

$$T = 250\frac{250}{300} = 208.33\ \text{kN}, \qquad C = \frac{250}{\sin 50.19^\circ} = 325.43\ \text{kN}$$

Keep full precision in the calculation; displayed substitutions are rounded.

03 Calculate tie area and stress

$$A_s = 2\frac{\pi 20^2}{4} = 628.32\ \text{mm}^2, \qquad \sigma_t = \frac{208333.33}{628.32} = 331.57\ \text{MPa}$$

Area to meet the adopted 400 MPa comparison limit: 520.83 mm².

04 Calculate nominal strut and contact stresses

$$\sigma_s = \frac{325427.07}{300 \times 120} = 9.04\ \text{MPa}, \qquad \sigma_b = \frac{250000}{300 \times 100} = 8.33\ \text{MPa}$$

These are average demand stresses on assumed areas; no concrete effectiveness or confinement factors are generated.

Individual adopted-limit comparisons

Quantity	Demand	Limit	Ratio	Result
Tie average stress	331.57 MPa	400 MPa	0.829	PASS
Nominal strut average stress	9.04 MPa	10 MPa	0.904	PASS
Vertical bearing-face average stress	8.33 MPa	12 MPa	0.694	PASS

208.33 kN
Tie / anchorage force demand

325.43 kN
Compression strut force

50.00 kN·m
Moment at column face

Keep these results separate. Anchorage capacity, full nodal-zone strength, splitting reinforcement, supporting-column capacity and serviceability: **NOT ASSESSED**. The three green comparisons above do not resolve those checks.

4. Move the bearing. Review what changes.

Move the load from a = 200 mm to a = 300 mm while retaining V = 250 kN and z = 300 mm. The required tie force rises by **40%**. Increasing tie steel changes its stress but does not change the strut force.

Case	a mm	Tie bars count × mm	w_s mm	T kN	C kN	Tie limit	Strut limit
CB-01	200	2 × 20	120	208.3	325.4	PASS	PASS
CB-02	300	2 × 20	120	291.7	384.1	FAIL	FAIL
CB-03	300	3 × 20	120	291.7	384.1	PASS	FAIL
CB-04	300	3 × 20	150	291.7	384.1	PASS	PASS

Bearing stress stays 8.33 MPa in these four cases because the vertical load and contact area stay fixed. CB-04 changes the *assumed effective strut width*; it does not show that adding concrete or moving reinforcement automatically provides that width. Anchorage and full nodal assessment remain open in every row.

Inputs and guards for the calculator

Make V, a, e, z, b, h, p, c_t, l_b, w_s, bar count, bar diameter and the three comparison stresses explicit inputs with units. Suggested demo dropdowns: two or three bars; 16, 20 or 25 mm diameter. Default to CB-01.

- Require positive dimensions, areas and comparison limits, V > 0, e ≥ 0 and a positive integer bar count.
- Keep node centres inside the declared envelope: $c_t > 0$ and $c_t + z < h$. Require $0 \le a - l_b/2$ and $a + l_b/2 \le p$ so the contact fits on the projection.
- These guards check input consistency only. Node-face geometry, strut fit, bar cover/spacing, minimum reinforcement and anchorage need a separate design assessment.

What to show in Fontana

1. **Read the source:** identify a, e and z, the load line and the assumed limits.
2. **Create from the image:** attach the companion section PNG, confirm the interpreted values, and build cited LaTeX workings with the image retained.
3. **Change a detail:** move the bearing outward and inspect the tie and strut comparisons. Use the table as reference arithmetic; a batch run is optional.

Source and data provenance

All prose, geometry, figures and fictional case data in this note were prepared for the Fontana worked example. The companion case and expected-result CSVs are calculated from equations (1)–(6). No source publication figure or standards table is reproduced.

FHWA, Strut-and-Tie Modeling (STM) for Concrete Structures — Design Examples, FHWA-NHI-17-071 (2017): glossary (printed iii–iv), and the distinction between member-force analysis and tie anchorage (printed 1-32). Background context only; the publication does not endorse this example or supply its assumed stress limits.

> **For a real design:** adopt an applicable structural method and its material design resistances, justify the load path and areas, and complete the omitted checks. This note supplies an auditable demonstration calculation, not a construction design.