EN 1992-1-1:2004 Concrete Column Design

Overview

This calculator is for the design of reinforced non-prestressed concrete columns as per EN 1992-1-1:2004, Eurocode 2: Design of concrete structures. The following calculations are performed:

Column slenderness is determined in each direction depending on user inputs.
Design bending moments are calculated based on slenderness.
Moment capacities are derived from interaction diagrams, which are drawn based on the section properties of the column.
Shear capacities of the section are determined using the inclined strut truss model.
Detailing checks are performed on the section.

Assumptions

General

Design Basis

This tool has been created in alignment with the design principles set out in EN 1992-1-1:2004.
The design equations for circular columns are supplemented by the research paper *"Shear design of circular concrete sections using the Eurocode 2 truss model"* by Orr et al.

'Best Practice'

Users have the option of toggling whether 'best practice' values should be applied throughout the calculation or not. These values comprise the following:

Single curvature bending - an additional term, M02 + M2, is added to the moment calculation for slender members if the column is bending in single curvature:

$$M_{Ed} = \max\left[M_{0e} + M_2\ ;\ M_{02}\ ;\ M_{01} + 0.5\,M_2\ ;\ M_{min}\ ;\ M_{02} +\ M_2\right]$$

Slenderness limit, λ_{lim} - absolute maximum value of 50 or:

$$\frac{15.4 \cdot C}{\sqrt{n}}$$

Biaxial Bending Utilisation of circular columns is taken as the square root of equation 5.39:

$$\sqrt{\left(\frac{M_{Edz}}{M_{Rdz}}\right)^a + \left(\frac{M_{Edy}}{M_{Rdy}}\right)^a} \leq 1.0$$

Shear web width b_w of circular columns is calculated using the equivalent rectangle as discussed in section *'Calculation of b_w*".
Biaxial Shear Utilisation is calculated as the resultant of the mono-axial shear utilisations in the 'Y' and 'Z' axes. EN1992-1-1:2004 does not provide specific guidance on how to consider a concrete section for biaxial shear, so this value is provided as a conservative safeguard:

$$\sqrt{\left(\frac{V_{Edz}}{V_{Rdz}}\right)^2 + \left(\frac{V_{Edy}}{V_{Rdy}}\right)^2}$$

Maximum spacing of longitudinal bars set to 175mm, which assumes that the face of the column could be in tension. If best practice is not selected then the default value is 400mm, which assumes the section is in compression.
Minimum number of longitudinal bars in a circular column = 6.
Minimum bar spacing:

Bar Diameter (mm)	Minimum Spacing (mm)
12	40
16	45
20	50
25	55
32	70
> 32	90

Section Analysis

Interaction Diagrams

The bending capacity of the concrete column is derived from interaction diagrams drawn for each axis. The interaction line is plotted by calculating values of 'M' and 'N' at varying depths of the neutral axis. This is done by determining the strains in the concrete and reinforcement bars for a given depth of the neutral axis. These strains can be converted into forces, which can then be used to calculate the maximum axial load and bending moment that the column can resist for that neutral axis depth.

Notes:

Moments are taken about the plastic centroid of the section.
The concrete block strength η.f_{cd} is reduced by 10% for circular sections as per 3.1.7(3).
The resultant concrete force is assumed to act at the centroid of the rectangular stress block.
For rectangular sections, this is taken as half the height of the block.
For circular sections, this is calculated by finding the centroid of the segment in compression, where the height of the segment is equal to λ.X.

Column Design

Design Moments

The moments used to design a concrete column depend on the slenderness of the column in the considered axis. If the column is not slender (or 'stocky'), then the column only needs to be checked for first order moments. The column must be designed for second order moments for each axis about which it is slender.

Users have the option to directly provide second-order moments to be used in the calculation. This option is only available if the column is slender.

The work flow for calculating second order moments based on the first order input is as follows:

Calculate Slenderness:

5.8.3.2 (Eq. 5.14)

$$\lambda = \frac{l_0}{i}$$

5.8.3.1 (Eq. 5.13N)

$$\lambda_{\text{lim}} = \frac{20ABC}{\sqrt{n}}$$

Calculate Moment

Imperfection Moment: 5.2(7) (Eq. 5.2)

$$M_{imp} = e_i \cdot N_{Ed}$$

$$e_i = \frac{\theta_i \cdot l_0}{2}$$

Minimum Moment: 6.1(4)

$$M_{min} = e_0 \cdot N_{Ed}$$

$$e_0 = \max\left[\frac{h}{30}\ ;\ 20\right]$$

Non-Slender Columns:

$$M_{Ed} = \max\left[M_{02}\ +\ M_{imp}\ ;\ M_{min}\right]$$

Slender, Braced Columns:

$$M_{Ed} = \max\left[M_{0e} + M_2\ ;\ M_{02}\ ;\ M_{01} + 0.5\,M_2\ ;\ M_{min}\right]$$

Slender, Unbraced Columns:

$$M_{Ed} = \max\left[M_{0e} + M_2\ ;\ M_{min}\right]$$

Bending Capacity

The bending moment capacity is calculated in each axis by plotting the coordinates of the design forces (axial load and bending moment) on the interaction diagrams. A line is drawn parallel to the x-axis, which intersects this coordinate (N = design axial load). The moment capacity is taken at the point where this line intersects the interaction line.

Biaxial Bending Check

Check column for biaxial bending if: *5.8.9 (Eq 5.38.a, 5.38.b)*

$$\frac{\lambda_y}{\lambda_z} \le 2 \quad \text{and} \quad \frac{\lambda_z}{\lambda_y} \le 2$$

$$\text{and}$$

$$\left(\frac{e_y/h_{eq}}{e_z/b_{eq}}\right) \le 0{,}2 \quad \text{or} \quad \left(\frac{e_z/b_{eq}}{e_y/h_{eq}}\right) \le 0{,}2$$

Biaxial utilisation is calculated as: *5.8.9 (Eq 5.39)*

$$\left(\frac{M_{Edz}}{M_{Rdz}}\right)^a + \left(\frac{M_{Edy}}{M_{Rdy}}\right)^a \le 1{,}0$$

Shear Capacity

The applied shear force is initially checked against the shear capacity of the concrete only. If the resistance exceeds the applied shear, then the capacity of the section is taken as that of the concrete, $V_{Rd} = V_{Rd,c}$.

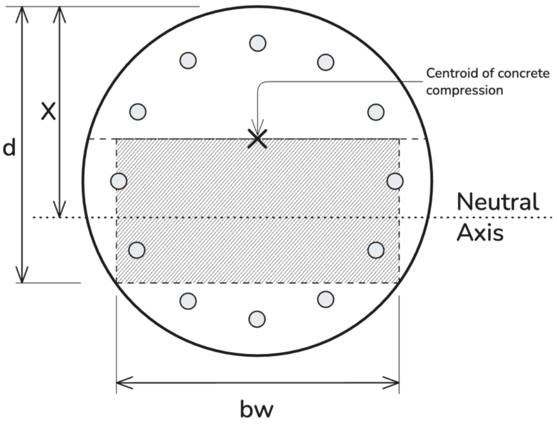
If the applied shear is greater than the capacity of the concrete, then the resistance of the section is taken as the minimum of the shear reinforcement capacity and the crushing strength of the inclined concrete strut, $V_{Rd} = \min[\ V_{Rd,max};\ V_{Rd,s}\ ]$.

The values for $V_{Rd,c}$, $V_{Rd,max}$ and $V_{Rd,s}$ are calculated using the equations set out in En 1992-1-1:2004 for rectangular sections. The equations for circular columns are taken from *"Shear design of circular concrete sections using the Eurocode 2 truss model"*.

For both shapes, the upper and lower bound value for the concrete strut capacity, ($V_{Rd,max}$) are determined for cotθ = 1 and cotθ = 2.5 respectively. If the applied shear force V_{Ed} is greater than the upper bound value, then cotθ = 2.5 is used to define the strut angle. If the shear force is less than the lower bound, cotθ = 1 is used. When V_{Ed} is between these two values, the design angle of θ is iteratively increased until $V_{Rd,max} > V_{Ed}$. This angle is used in the rest of the calculation.

Calculation of b_w

The section width for rectangular sections is taken as the perpendicular dimension to the direction of the applied shear force. For circular sections, when best practice is applied, an 'equivalent rectangle' is used to calculate the compression strut cross-section. The width of this rectangle 'b_w' is taken as the smaller of the width of the circular section at the centroid of the compression chord and the width of the circular section at the centroid of tension reinforcement. If best practice is not applied, the shear web width is taken as the diameter of the circle.



Approximation of z

This calculator uses 0.9d as an approximation for the internal lever arm of the section when calculating the shear reinforcement capacity. This is a suggested value in EN 1992-1-1:2004 for members without axial load, and as such may not be accurate.

Concrete Strut Strength

This calculator allows for a column to be designed with an axial tension force. When calculating the concrete strut capacity in clause 6.2.3(3) (Eq 6.9), the value of f_{cd} needs to be modified to suit tension conditions in the concrete strut. To do this, the concrete strength is calculated according to 6.5.2(2), using strength reduction factors of 0.6.v' (6.57N).

Shear Capacity Of Rectangular Columns

Concrete Shear Capacity, $V_{Rd,c}$:

6.2.2 (Eq 6.2.a, 6.2.b)

$$V_{Rd,c} = \left[C_{Rd,c} \cdot k(100 \cdot \rho_l \cdot f_{ck})^{1/3} + k_1 \cdot \sigma_{cp} \right] \cdot b_w \cdot d$$

$$V_{Rd,c,min} = (v_{min} + k_1 \cdot \sigma_{cp}) \cdot b_w \cdot d$$

Inclined Concrete Strut Capacity, $V_{Rd,max}$:

6.2.3(3) (Eq 6.9)

$$V_{Rd,max} = \alpha_{cw} \cdot b_w \cdot z \cdot \nu_1 \cdot f_{cd} \,/\, (\cot\theta + \tan\theta)$$

Shear Reinforcement Capacity, $V_{Rd,s}$:

6.2.3(3) (Eq 6.8)

$$V_{Rd,s} = \frac{A_{sw}}{s} \cdot z \cdot f_{ywd} \cdot \cot\theta$$

Shear Capacity Of Circular Columns

Concrete Shear Capacity, $V_{Rd,c}$:

(Eq 17), derived from 6.2.2(2) (Eq 6.4)

$$V_{Rd,c} = \frac{3\pi r^2}{4} \cdot \sqrt{(f_{ctd})^2 + \sigma_{cp} \cdot f_{ctd}}$$

Inclined Concrete Strut Capacity, $V_{Rd,max}$:

6.2.3(3) (Eq 6.9)

$$V_{Rd,max} = \alpha_{cw} \cdot b_w \cdot z \cdot \nu_1 \cdot f_{cd} \,/\, (\cot\theta + \tan\theta)$$

Shear Reinforcement Capacity, $V_{Rd,s}$:

(Eq 18) derived 6.2.3(3) (Eq 6.8)

$$V_{Rd,s} = \lambda_1 \cdot \lambda_2 \cdot \frac{A_{sw}}{s} \cdot z \cdot f_{ywd} \cdot \cot\theta$$

$$\lambda_1 = 0.85 \; ; \; \lambda_2 = 1.0$$

Effects Of Creep

Users have several options for defining the effects of creep on the column they are designing.

If the column is non-slender, then default values may be used in the calculations. This will set the value of 'A' to 0.7 in Eq 5.13N for the slenderness limit.

There are no default values specified for the creep factor used to calculate curvature (K_φ) in EN 1992-1-1: 2004. If the column is determined to be slender, the user must input their own value or provide sufficient data to calculate the effective creep ratio φ_{ef}.

Effective Creep Ratio *5.8.4 (Eq 5.19)*

$$\varphi_{ef} = \varphi_{(\infty,t_0)} \cdot \frac{M_{0Eqp}}{M_{0Ed}} \equiv \varphi_{(\infty,t_0)} \cdot \frac{N_{0Eqp}}{N_{0Ed}}$$

Annex B of EN 1992-1-1:2004 is used to calculate $\varphi(\infty,t_0)$. This calculator substitutes quasi-permanent moment for axial load, as this is deemed to be comparable and simpler to derive.

Change Log

November 2025

Moved additional moment calculation term M2 + M02 for single curvature behind best-practice.
Resolved shear table values updating in report.
October 2025

Update creep factor calculation to remove 0 default.
Updated strain calculation in compression bars to calculate and subtract equivalent concrete strain to ensure the force is not double counted.
Moved shear web width calculation for circular columns behind best practice toggle.
Added logic to calculate the 'resultant' biaxial utilisation for circular columns and added behind best practice toggle.
Updated report styling to full width and generally refactored report layout.
Split detailing check for maximum spacing into max spacing general and max distance to restrained bar.
Added biaxial shear check to best practice.
Added M02 + M2 term for max moment in columns with single curvature.

Feedback

We're constantly looking to expand and improve our product offering!

If you have any requests or feedback, please submit them by following Library → Calculator Info → Feedback.