

Shear Strength Design Optimization

of Concrete Beams with rectangular web (stirrup reinforced sections)

attempting to follow
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See following collapsed area (expandable) comments



$b := 150\text{ cm}$ width of rectangular beam $h := 100\text{ cm}$ total depth of beam

$k_0 := 0.9$ where $d_0 := k_0 \cdot h$ $d_0 = 90\text{ cm}$ depth of the axis of the lowest reinforcing steel

$k_v := 0.8$ where $d_v := k_v \cdot h$ $d_v = 80\text{ cm}$ depth on which the shear force is assumed to be uniformly distributed.
you may as well directly enter d_0 and d_v entirely forfeiting the ks at left

$M := 0\text{ m}\cdot\text{ton}$ $V := 1270\text{ kN}$ $\phi_v := 0.85$ don't enter ϕ_v less than 0.6

These are the (**factored** or enlarged) moment and shear forces concurrently present at the section where the shear design is being made.

The shear strength of the section will be reduced by the multiplying factor ϕ_v

$A_{sl} := 8.04\text{ cm}^2$ This area of steel is known to reinforce the (under M) tensile side of the section, whichever it is

$f_{sly} := 400\text{ MPa}$ $f_{sty} := 400\text{ MPa}$ $E_s := 200000\text{ MPa}$

Yield stress of the longitudinal and stirrup's steel, respectively

Young's modulus for both steels

$f_c := 20\text{ MPa}$ This is the assumed real compressive strength of the concrete.
Depending upon the code, could be the evaluated as real or a reduced one.

$P := 0\text{ ton}$ This is the axial force acting in the section

- For normal reinforced concrete beams, $P=0$
- Enter the value as **negative if the section is compressed**.
- Enter the value positive if the beam is subject to tensile stresses

We collapse the (expandable) calculations



$\text{Angle}_{\text{strut_horizontal}} := \theta$ $\text{Angle}_{\text{strut_horizontal}} = 45\text{ deg}$

This is the angle that the axis along the principal compressive stress (along the strut) forms with the beam's axis.

$$\text{Strut}_{\text{Compressive_stress}} := \text{MPa} \cdot \sigma_d(\epsilon_d, \epsilon_r)$$

$$\text{Strut}_{\text{Compressive_stress}} = -1.25 \text{ MPa}$$

compression fares negative

Use this value to check if you are nearing or faulting a (per code) limiting compressive stress in the strut due to shear.

$$\text{Strut}_{\text{Transv_tensile_stress}} := \text{MPa} \cdot \sigma_r(\epsilon_r)$$

$$\text{Strut}_{\text{Transv_tensile_stress}} = 1.24 \text{ MPa}$$

$$f_{cr} \cdot \text{MPa} = 1.48 \text{ MPa}$$

$$\text{Governing_ultimate_shear}_{\text{stress}} := \text{MPa} \cdot \nu_{lt}(\epsilon_d, \epsilon_r, \theta)$$

$$\text{Governing_ultimate_shear}_{\text{stress}} = 1.25 \text{ MPa}$$

weighed concrete tensile strength that makes the model correlate well with failures (and so shouldn't be changed)

Note that this governing shear stress is not the maximum available in general of the b-h section, but the one that governs the **current** case when the shear reinforcement ratio has been optimized (minimized) and so uses the less expensive shear reinforcement to be tolerated.

$$\text{Strain}_{\text{longitudinal_steel}} := \epsilon_l(\epsilon_d, \epsilon_r, \theta)$$

$$\text{Strain}_{\text{longitudinal_steel}} = 0.0000058$$

$$\text{Stress}_{\text{longitudinal_steel}} := \text{MPa} \cdot f_{sl}(\epsilon_d, \epsilon_r, \theta)$$

$$\text{Stress}_{\text{longitudinal_steel}} = 1.17 \text{ MPa}$$

as inflicted per the ultimate shear mechanism on the area dedicated to sehar, with the minimized shear reinforcement (**non additive** to those moment derived, since we have separated the dedicated areas for shear and moment)

$$\text{Strain}_{\text{in_stirrups}} := \epsilon_t(\epsilon_d, \epsilon_r, \theta)$$

$$\text{Strain}_{\text{in_stirrups}} = 5.8465 \times 10^{-6}$$

$$\text{Stress}_{\text{in_stirrups}} := \text{MPa} \cdot f_{st}(\epsilon_d, \epsilon_r, \theta)$$

$$\text{Stress}_{\text{in_stirrups}} = 1.17 \text{ MPa}$$

$$\text{Shear}_{\text{distortion}} := \gamma_{lt}(\epsilon_d, \epsilon_r, \theta)$$

$$\text{Shear}_{\text{distortion}} = 0.00013$$

$$\text{Ultimate}_{\text{shear_strength}} := \text{MN} \cdot V_p(\epsilon_d, \epsilon_r, \theta)$$

$$\text{Ultimate}_{\text{shear_strength}} = 152.36 \text{ ton}$$

Note that this is not the ultimate shear strength of the generic b-h, but when reinforced with at least the minimum permissible reinforcement shear ratio and for the other stated conditions of the problem.

$$\phi_v \cdot \text{Ultimate}_{\text{shear_strength}} = 1270 \text{ kN}$$

$$\underline{\underline{V}} := \text{MN} \cdot V$$

$$V = 1270 \text{ kN}$$

must be very close to V to meet the strength requirement
(may be a bit less due to the built-in tolerances in the optimization problem)

$\text{Required}_{\text{shear_reinf_ratio}} := \rho_t(\epsilon_d, \epsilon_r, \theta)$

$\text{Required}_{\text{shear_reinf_ratio}} = 0.67 \frac{1}{1000}$

$\text{Minimum}_{\text{shear_ratio}} := \rho_{t_min}$

$\text{Minimum}_{\text{shear_ratio}} = 0.67 \frac{1}{1000}$

Stirrups and shear reinforcement plane separation choice

Stirrups' diameter $\phi := 16\text{-mm}$ $N_{\text{legs}} := 2$ per shear reinforcement plane

We collapse the (expandable) calculations



$s = 30\text{ cm}$

$\frac{\rho_{t_after_code}}{\text{Required}_{\text{shear_reinf_ratio}}} = 1.33$