

Contribution of Stirrups to Shear Strength for beams with webs well reinforced in shear

Don't use for slabs, mats or joists not reinforced in shear



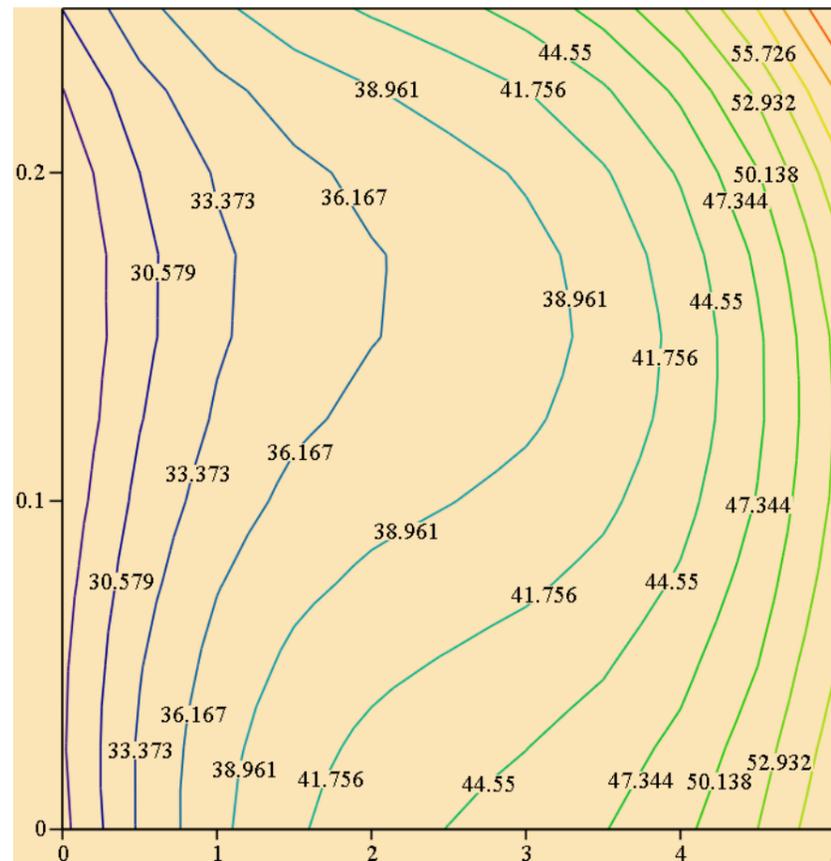
The following serves to interpolate values in Table 7-3 of Collins & Mitchell 1997 p. 361 in sections that have at least minimum shear reinforcement as to warrant typical crack separations to be lesser than 30 cm. See in the text the general conditions that apply. Note that shear field action as here implied is a 2-D affair and so you shouldn't rely this sheet to properly cover 3-D cases such 2-way mats where there are tensile stresses in 2 orthogonal directions which can cause more reduction in the concrete shear contribution than the 2-D case. For these cases still go code. Uncollapse area to see calculations.

$$\phi_s := 0.85$$

shear strength reduction factor



Shear - tensile strain interaction for well reinforced in shear beams, to give Strut Angle, as per Table 7-3 in Collins & Mitchell 1997, p. 361



Enable by right-click in the graph, Flying menu... Format...Special...Numbered to see values

$\frac{\theta}{\text{deg}}$

- Enter in abscissas with longitudinal strain ϵ_x in thousandths. Top value charted is $5 \cdot 10^{-3}$ or 0.005 then. For compressive strains enter 0. To be generally conservative the longitudinal

strain should be from factored loads and read where it is maximum and affecting shear, and this can't be other place than the main tensile reinforcement level, be it from positive or negative moments (it does not matter, since we are charting interaction with a tensile strain, whichever its position). However this stance may be overly conservative, and it can be more reasonable (see p. 357 in the text) to use the strain at the center of gravity level, which is acceptable for beams with shear reinforcement. Don't use this chart if there is not shear reinforcement, so don't use for slabs or mats not reinforced in shear.

- Enter in ordinates with the ratio of shear on effective (web) shear section (bounded by

effective mechanical arm) to specified concrete strength, that is $\frac{V_u}{b_w \cdot \text{mech}_{\text{arm}}}$ f_c

- Read within the chart the θ strut angle value to be used in the evaluation of stirrups contribution to shear strength and for strut and tie models.

Example of use of the chart

$f_c := 35 \cdot \text{MPa}$

Factored shear close but not over one support where

$\epsilon_x := 0.0001$

(Over or at face of supports strut and tie analysis is better)

You obtain ϵ_x by some compatibility of deformation

analysis of the section under bending. It may be at the most tensile reinforcement level (negatives or positives, whichever it is) (conservative but recommended by authors, maybe due to some restrictions observed while building the table) or at center of gravity of the section level (usual, were not for the authors recommendation).

input in abscissas, where 1 means 0.001 or ten times our input value

$sr := 0.1$

this is $\frac{V_u}{b_w \cdot \text{mech}_{\text{arm}}}$ f_c

shear stress to compressive stress ratio, enter it in ordinates

We read in the table θ to be

$\theta := 27 \cdot \text{deg}$

This strut angle can be used in similar manner to the 45-deg Morsch assumption, and is required for the calculation of the stirrups capacity, both within span (common formulation) and at support (strut and tie convention).

$$A_v := 4.02 \cdot \text{cm}^2$$

$$s := 15 \cdot \text{cm}$$

$$b_w := 150 \cdot \text{cm}$$

$$h := 100 \cdot \text{cm}$$

$$d := 0.9 \cdot h$$

$$\text{mech}_{\text{arm}} := 0.9 \cdot d$$

$$f_y := 400 \cdot \text{MPa}$$

Then **stirrups** contribution to shear strength is

$$\phi_s \cdot \frac{A_v \cdot f_y \cdot \text{mech}_{\text{arm}} \cdot \frac{1}{\tan(\theta)}}{s} = 1448.52 \text{ kN}$$

limit **stirrups** shear strength contribution at the section to be compared with factored shears on $b_w \cdot \text{mech}_{\text{arm}}$

$$\phi_s \cdot \frac{A_v \cdot f_y \cdot \text{mech}_{\text{arm}} \cdot \frac{1}{\tan(\theta)}}{s} = 325.64 \text{ kip}$$

$$\frac{\phi_s \cdot \frac{A_v \cdot f_y \cdot \text{mech}_{\text{arm}} \cdot \frac{1}{\tan(\theta)}}{s}}{b_w \cdot \text{mech}_{\text{arm}}} = 1.19 \text{ MPa}$$

$$\frac{\phi_s \cdot \frac{A_v \cdot f_y \cdot \text{mech}_{\text{arm}} \cdot \frac{1}{\tan(\theta)}}{s}}{b_w \cdot \text{mech}_{\text{arm}}} = 12.16 \frac{\text{kgf}}{\text{cm}^2}$$

$$\frac{\phi_s \cdot \frac{A_v \cdot f_y \cdot \text{mech}_{\text{arm}} \cdot \frac{1}{\tan(\theta)}}{s}}{b_w \cdot \text{mech}_{\text{arm}}} = 172.91 \text{ psi}$$

When the web is to be taken enough reinforced in shear for the above procedure be apt for use

Whichever your positive result with the concrete contribution to shear strength be, your web **MUST** respect the inferior limits for shear reinforcement established in ACI 318.

Alternatively, for your web be properly reinforced in shear you must have (criteria taken from Rangan et al.)

$$\rho_{t_min} := \frac{0.06 \cdot \sqrt{\frac{f_c}{\text{MPa}}}}{\frac{f_y}{\text{MPa}}}$$

$$\rho_{t_min} = 0.000887 \quad f_y \text{ of stirrups}$$

$$\frac{A_v}{b_w \cdot s} = 0.001787$$