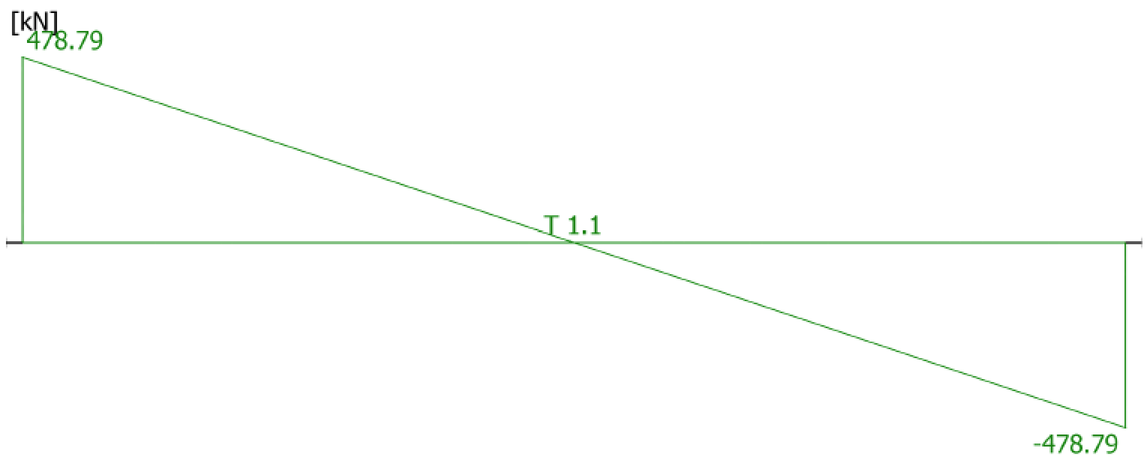
Transversal reinforcement

The ULS shear force envelope is the following:



Syntethic values table:

Span	Section	Abscissa	Position	V_{Ed}
		(mm)		(kN)
1	Left Support	0	Top	478.79
			Bottom	0.00
1	Right Support	10000	Top	0.00
			Bottom	-478.79
1	MInf	5000	Top	0.00
			Bottom	0.00
1	VInf	10000	Top	0.00
			Bottom	-478.79

V_{Ed} : ULS design shear force.

<u>Transversal reinforcement calculation</u>

The calculation will be detailed for section V_{inf} (abscissa 10000 mm).

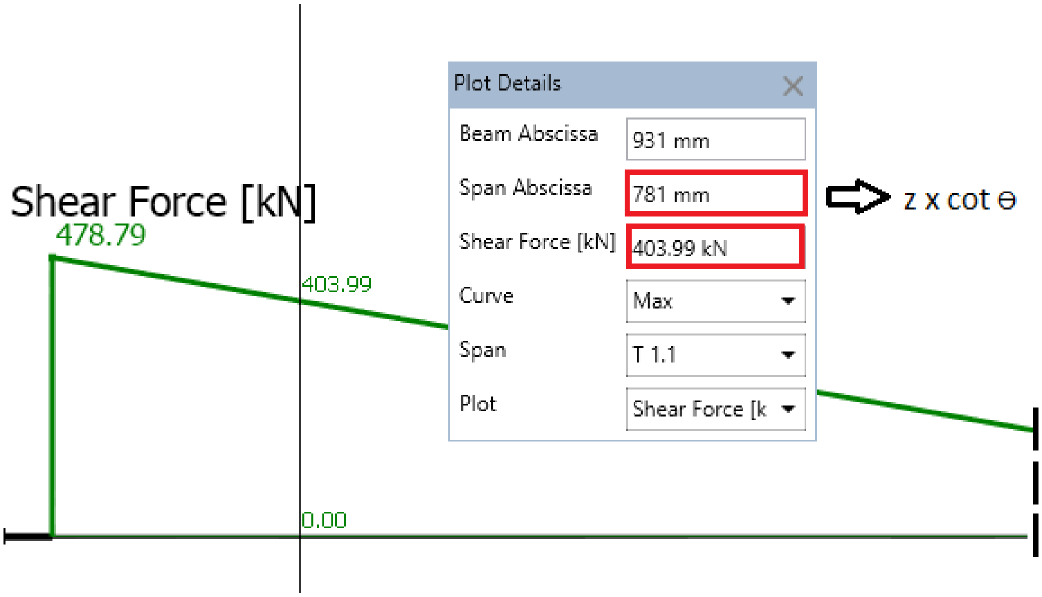
The value of the effective height (d) is defined automatically according to the real reinforcement in place.

Design shear force

The value for design shear force can be optimized considering $V_{Ed,red}$ instead of V_{Ed} according to article §6.2.3 (5) from EN 1992-1-1]:

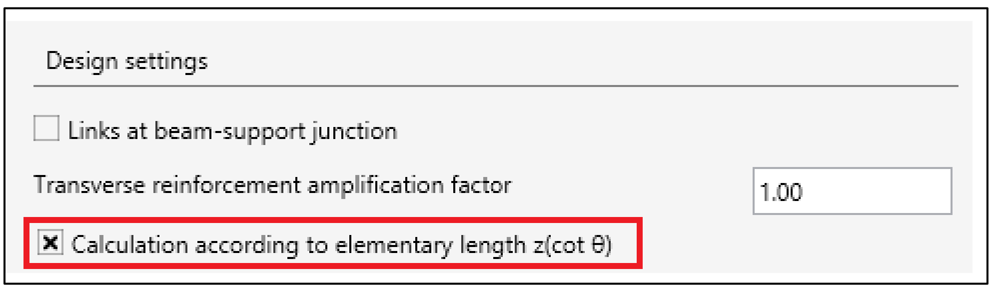
In regions where there is no discontinuity of V_{Ed} (e.g. for uniformly distributed loading) the shear reinforcement in any length increment l = z (cot θ + cot α) may be calculated using the smallest value of V_{Ed} in the increment.

$z = 0.9 \times d = 0.9 \times 868 = 781.2$ mm



$V_{Ed,red} = 403.99$ kN

This optimization is done if the user checks the option "Calculation according to elementary length z(cotϴ)" in the Reinforcement Assumptions dialog, Transversal tab:



In this example, the option is checked and instead of V_{Ed} the value of $V_{Ed,red}$ will be used.

First of all the program verifies the following relation:
$V_{Rd,c} \geq V_{Ed}$

If the relation is satisfied it means that the transversal reinforcement is not required.

$$V_{Rd,c} = \max\begin{cases}[C_{Rd,c} \times k \times (100 \times \rho_L \times fck)^{\frac{1}{3}} + k_1 \times \sigma_{cp}] \times b_w \times d \\ (\nu_{min} + k_1 \times \sigma_{cp}) \times b_w \times d\end{cases} \quad [§6.2.2(1)\text{Note from EN1992} - 1 - 1]$$

$$C_{Rd,c} = \frac{0.18}{\gamma_c} = \frac{0.18}{1.5} = 0.12 \ [§6.2.2(1)\ \text{Note from EN1992} - 1 - 1]$$

$$k = 1 + \sqrt{\frac{200}{d}} \leq 2$$

$$k = 1 + \sqrt{\frac{200}{868}} = 1.48$$

Longitudinal reinforcement ratio:

$$\rho_L = \frac{Asl}{b_w \times d} \leq 0.02$$

$$\rho_L = \frac{7.08}{35 \times 86.8} = 2.33 \times 10^{-3}$$

$$\nu_{min} = \frac{0.053}{\gamma_c} \times k^{\frac{3}{2}} \times \sqrt{fck} = \frac{0.053}{1.5} \times 1.48^{\frac{3}{2}} \times \sqrt{25} = 0.31 \frac{MN}{m^2}$$

$$\sigma_{cp} = \frac{N_{Ed}}{A_c} < 0.2 \times fcd$$

$$\sigma_{cp} = 0 \frac{MN}{m^2}$$

$$V_{Rd,c} = \max \begin{cases} [C_{Rd,c} \times k \times (100 \times \rho_L \times fck)^{\frac{1}{3}} + k_1 \times \sigma_{cp}] \times b_w \times d \\ (\nu_{min} + k_1 \times \sigma_{cp}) \times b_w \times d \end{cases}$$

$$V_{Rd,c} = \max \begin{cases} \left[0.12 \times 1.48 \times (100 \times 2.33 \times 10^{-3} \times 25)^{\frac{1}{3}} + 0.15 \times 0\right] \times 0.35 \times 0.868 \times 10^3 \\ (0.31 + 0.15 \times 0) \times 0.35 \times 0.868 \times 10^3 \end{cases}$$

$$V_{Rd,c} = \max \begin{cases} 97.08 \text{ kN} \\ 94.18 \text{ kN} \end{cases}$$

$V_{Rd,c} = 94.18 \text{ kN} \geq V_{Ed,red} = 403.99 \text{ kN}$ Not satisfied

The relation $V_{Rd,c} \geq V_{Ed}$ is not satisfied and it means that transversal reinforcement is required.

The shear verification is accomplished if the following relation is satisfied:

$$V_{Rd} \geq V_{Ed}$$

$$V_{Rd} = \min (V_{Rd,max}; V_{Rd,s})$$

$V_{Rd,max}$ is the design value of the maximum shear force which can be sustained by the member, limited by crushing of the compression struts.[§6.2.1.(1)P from EN 1992-1-1]

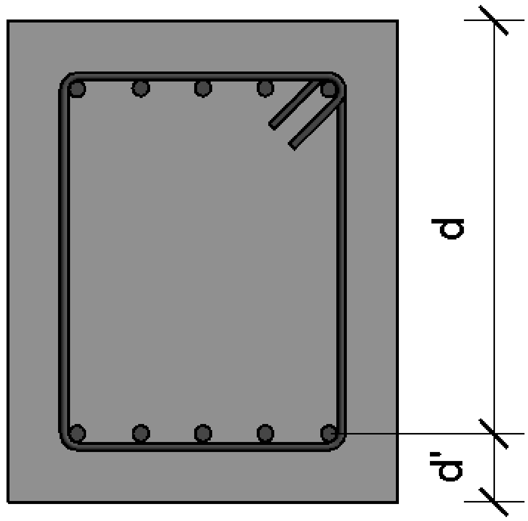
$V_{Rd,s}$ is the design value of the shear force which can be sustained by the yielding shear reinforcement. [§6.2.1.(1)P from EN 1992-1-1]

$$V_{Rd,max} = \frac{\alpha_{cw} \times b_w \times z \times \nu_1 \times f_{cd}}{\cot \Theta + \tan \Theta}$$

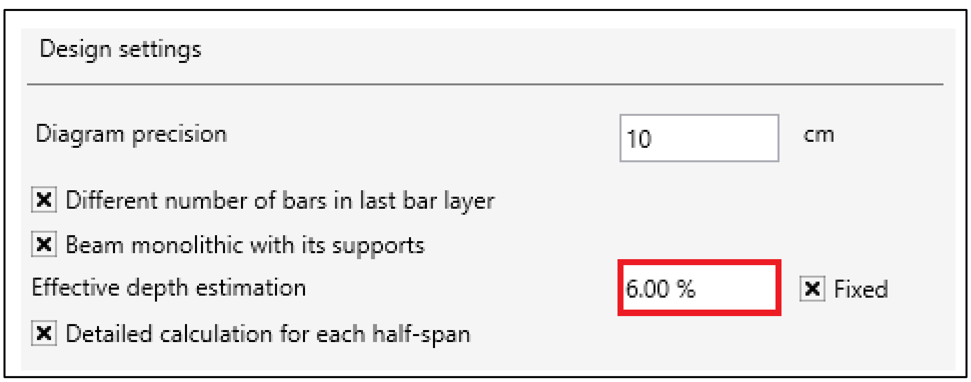
α_{cw} coefficient taking account of the state of the stress in the compression chord. [§6.2.3.(3) from EN 1992-1-1]

$\alpha_{cw} = 1.00$ for non-prestressed structures [§6.2.3.(3) Note 3 from EN 1992-1-1]

$b_w = 0.35$ m



Because of the fact that in the design phase the real d is not known the program will take into account when calculating the theoretical reinforcement the effective depth set as percentage in Reinforcement Assumptions dialog, Longitudinal tab.



The effective depth d will be estimated as : $d = h - \text{cover} - (6\% \times h)$

$$d = h - \text{cover} - (6\% \times h) = 950 - 25 - (6\% \times 950) = 868 \text{ mm}$$

There is the possibility to calculate more precise the value for d: after a first calculation with the initial value (default 6%), a first value of theoretical reinforcement and a certain configuration of real reinforcement are obtained.

Having this real reinforcement it can be estimated now more precise the real d value; then the theoretical reinforcement and real reinforcement are calculated again. At the end, the value of percentage "Effective depth estimation" is updated in the "Longitudinal" tab window.
So, in conclusion, the beam is calculated twice and there is displayed the "Effective depth estimation" percentage from the last calculation.

Just next to "Effective depth estimation" there is a check option which allows the user to block the re-evaluation of the d value.
If the user checks the option "Fixed", the "Effective depth estimation" percentage remains unchanged to its initial value, so the beam is calculated just one time.

$$d = 868 \text{ mm}$$

Inner lever arm:

$$z = 0.9 \times d = 0.9 \times 868 = 781.2 \text{ mm}$$

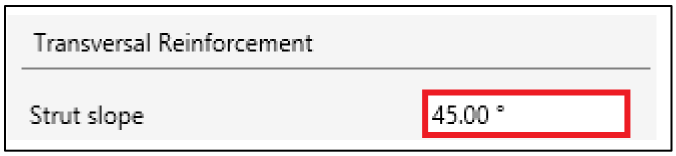
$$f_{cd} = 16.67 \frac{MN}{m^2}$$

ν_1 Strength reduction factor for concrete cracked in shear

$$\nu_1 = 0.6 \times \left[1 - \frac{f_{ck}}{250}\right] = 0.6 \times \left[1 - \frac{25}{250}\right] = 0.54$$

$$\Theta = 45°$$

The value for strut angle can be defined in Design Assumptions dialog, Transversal reinforcement section as Strut slope:



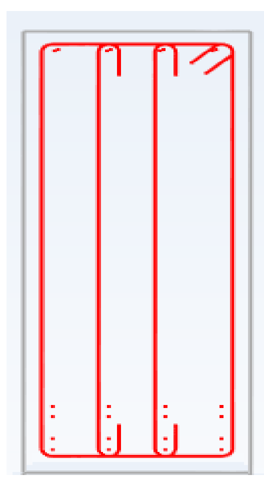
$$V_{Rd,max} = \frac{\alpha_{cw} \times b_w \times z \times \nu_1 \times f_{cd}}{\cot\Theta + \tan\Theta} = \frac{1 \times 0.35 \times 0.781 \times 0.54 \times 16.67 \times 10^3}{\cot 45 + \tan 45} = 1230.32 \text{ kN} > V_{Ed}$$

$$V_{Rd,s} = \frac{A_{sw}}{s} \times z \times f_{ywd} \times \cot\Theta => \frac{A_{sw}}{s} = \frac{V_{Ed}}{z \times f_{ywd} \times \cot\Theta} = \frac{403.99 \times 10^{-3}}{0.78 \times 434.78 \times \cot 45} \times 10^3 = 1.19$$

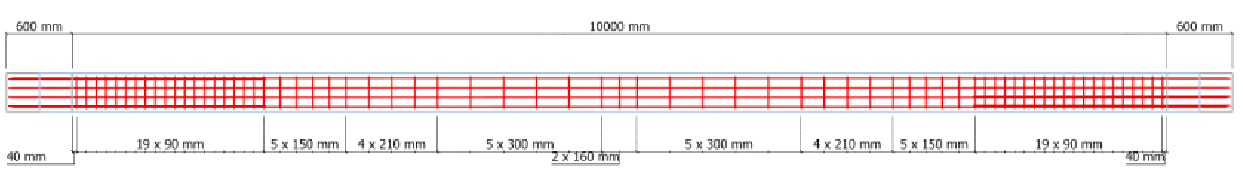
The program verifies if:

$$\frac{A_{sw,real}}{s_{real}} \geq \frac{A_{sw}}{s}$$

If not the spacing s_{real} is decreased or the transversal bars diameter is increased until the relation is verified .



From economical reasons, nine transversal distributions are generated:



Links package 1 (4ϕ6/90 mm):

$$\frac{A_{sw}}{s} = \frac{\frac{4 \times \pi \times 6^2}{4}}{90} = 1.26\ \text{mm(real)}$$

$$\frac{A_{sw}}{s} = \frac{V_{Ed,red}}{z \times f_{ywd} \times \cot \theta} = \frac{403.99 \times 10^{-3}}{0.781 \times 434.78 \times \cot 45} \times 10^3 = 1.189\ \text{mm(necessar)}$$

$$=> \frac{A_{sw}}{s}\text{real} > \frac{A_{sw}}{s}\text{necessar}$$

Minimal constructive dispositions

The minimal transversal reinforcement is defined according to §9.2.2 from EN 1992-1-1.

Minimum percentage

$$\rho_{w,min} = 0.08 \times \frac{\sqrt{fck}}{fywk} = 0.08 \times \frac{\sqrt{25}}{500} = 0.0008$$

$$A_{sw,min} = \rho_{w,min} \times b_w \times \sin(\alpha)$$

α is the angle between shear reinforcement and the longitudinal axis

$\alpha = 90°$

$$\left(\frac{A_{sw}}{s}\right)_{min} = \rho_{w,min} \times b_w \times \sin(\alpha) = 0.0008 \times 350 \times \sin(90°) = 0.28\ \text{mm}$$

$$\left(\frac{A_{sw}}{s}\right)\text{real} = 1.26\ \text{mm} > \left(\frac{A_{sw}}{s}\right)_{min} = 0.28\ \text{mm}$$