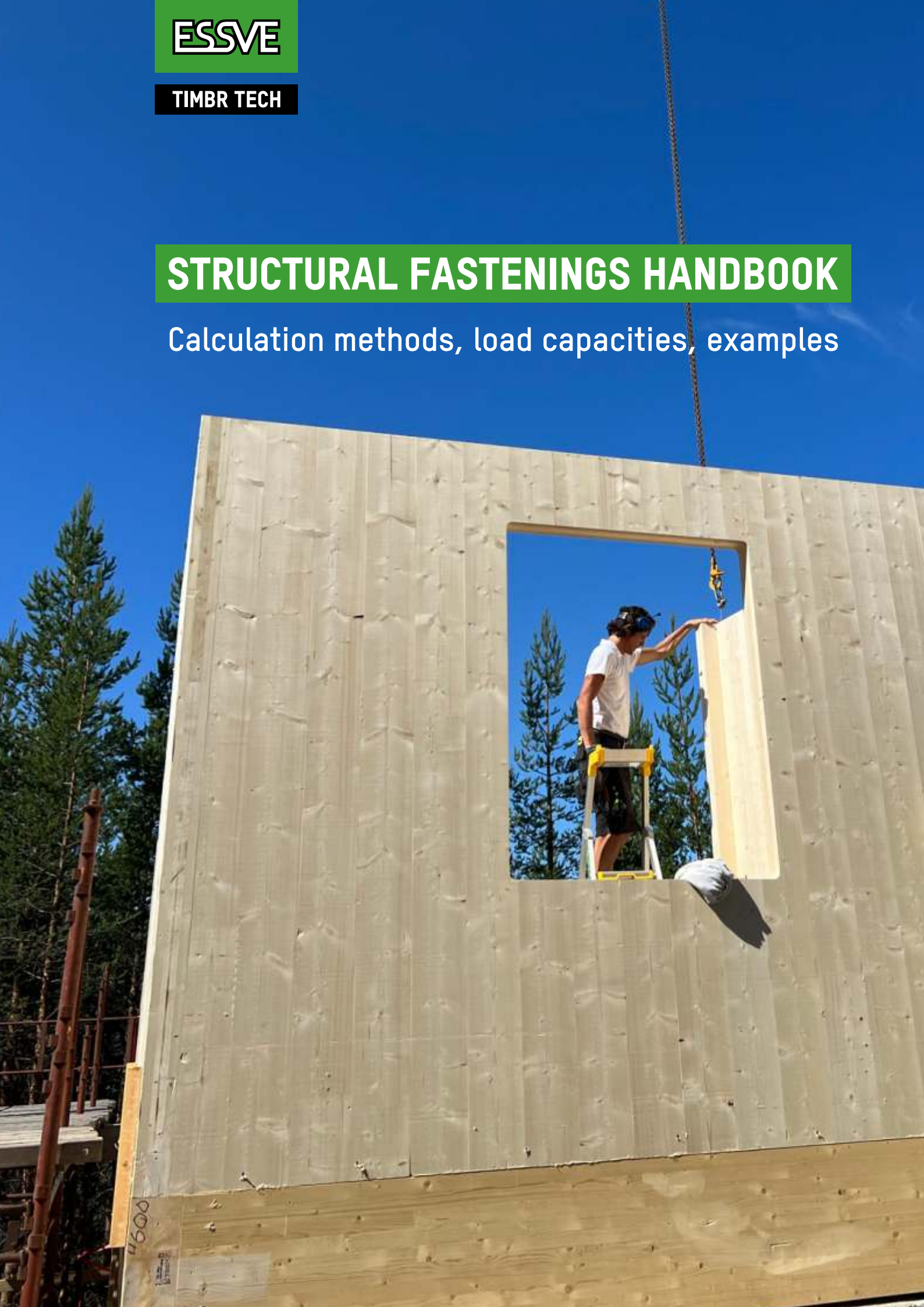


ESSVE

TIMBR TECH


STRUCTURAL FASTENINGS HANDBOOK

Calculation methods, load capacities, examples





GET
IT
DONE

A person in dark work clothes stands on a wooden dock extending into a calm lake. A bright green toolbox sits on the dock near the person. The sky is filled with soft, white clouds. In the distance, a small red buoy is visible in the water.

Our business idea is to make professional craftsmen's workday easier, safer and more profitable. We do this by offering products that get the job done. To be able to guarantee that our products deliver the right quality, are easy to use and fill the needs of true pros, we let hundreds of professional craftsmen take part in our product development. Their job is to test our new products under real life conditions in their daily work. That way, we continuously improve our products in a meaningful way, both through big development projects and small adjustments that make a real difference to real pros. We make sure to have the best solution for anyone whose job it is to **GET IT DONE.**

DEVELOPED FOR THE NORDIC CLIMATE

The starting point of our product development is always the worst conditions, the Nordic climate. Our products have been tried and tested to withstand temperature fluctuations from -35°C to 35°C within just a few months. These conditions put a high demand on both chemical and mechanical fasteners.



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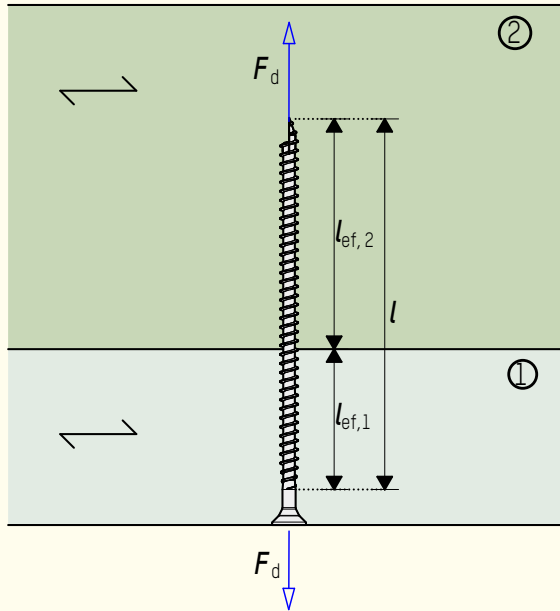
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FULLY THREADED SCREWS LOADED IN TENSION

A.1.1.1 general – connection between two timber elements



DETAILS

service class SC1

loading

permanent load: $F_{G,k} = 2.50$ kN

variable loads: $F_{N,k} = 1.25$ kN

(category A, duration of load medium-term)

construction elements

glue laminated timber GL24h

Wood Screw C-FT-8x350/340

$d = 8$ mm, $l = 350$ mm, $l_g = 340$ mm

$l_{ef,1} = 160$ mm, $l_{ef,2} = 180$ mm

action design value

$$F_{Ed} = \gamma_G \cdot F_{G,k} + \gamma_Q \cdot F_{N,k}$$

$$F_{Ed} = 1.35 \cdot F_{G,k} + 1.5 \cdot F_{N,k} = 1.35 \cdot 2.5 + 1.5 \cdot 1.25 = 5.25 \text{ kN} \hat{=} 5250 \text{ N}$$

determination of the load bearing capacity of the single screw

$$F_{ax,Rd} = \min \left\{ \begin{array}{l} \max \left\{ \begin{array}{l} \text{head pull-through resistance in element 1} \\ \text{withdrawal resistance in element 1} \end{array} \right\} \\ \text{withdrawal resistance in element 2} \\ \text{screw tension resistance} \end{array} \right\}$$

determination of the design value of the head pull-through resistance in element 1

$$F_{head,Rd} = f_{head,k} \cdot d_h^2 \cdot \left(\frac{\rho_{k,1}}{350} \right)^{0.8} \cdot \frac{k_{mod}}{\gamma_M}$$

$\rho_{k,1}$ 385 kg/m³ characteristic density of the timber element

k_{mod} 0.8 (SC1, GL24h, duration of load medium-term)

$f_{head,k}$ 12.4 N/mm² (acc. to ETA-22/0789:2023, table A6.7)

γ_M 1.30 (for connections in timber construction acc. to EN 1995-1-1, table 2.3)

$$F_{head,Rd,1} = 12.4 \cdot 15^2 \cdot \left(\frac{385}{350} \right)^{0.8} \cdot \frac{0.8}{1.30} = 1853 \text{ N}$$

determination of the design value of the withdrawal resistance in element 1:

$$F_{ax,Rd,1} = f_{ax,k,90} \cdot k_{ax} \cdot k_{sys} \cdot \left(\frac{\rho_k}{\rho_{k,ref}} \right)^{k_p} \cdot d \cdot l_{ef,1} \cdot \frac{k_{mod}}{\gamma_M}$$

TIMBER-TO-TIMBER CONNECTION CALCULATION EXAMPLE

- k_{ax} 1.0 für $30^\circ \leq \alpha \leq 90^\circ$
 k_{sys} 1.12 for 4 penetrated layers (acc. to ETA-22/0789:2023, table A6.6)
 ρ_k 350 kg/m³ characteristic density of the row material for the timber product
 $f_{ax,k,90}$ 13.1 N/mm² (acc. to ETA-22/0789:2023, table A6.1)
 $l_{ef,1}$ 160 mm

$$F_{ax,Rd,1} = 13.1 \cdot 1.0 \cdot 1.12 \cdot \left(\frac{385}{350}\right)^{1.10} \cdot 8 \cdot 160 \cdot \frac{0.8}{1.30} = 12834 \text{ N}$$

determination of the design value of the withdrawal resistance in element 2:

$$F_{ax,Rd,2} = f_{ax,k,90} \cdot k_{ax} \cdot k_{sys} \cdot \left(\frac{\rho_k}{\rho_{k,ref}}\right)^{kp} \cdot d \cdot l_{ef,2} \cdot \frac{k_{mod}}{\gamma_M}$$

- $f_{ax,k,90}$ 13.1 N/mm² (acc. to ETA-22/0789:2023, table A6.1)
 k_{ax} 1.0 for $30^\circ \leq \alpha \leq 90^\circ$
 k_{sys} 1.00 for solid wood
 ρ_k 350 kg/m³ characteristic density of the timber product
 $l_{ef,1}$ 180 mm

$$F_{ax,Rd,2} = 13.1 \cdot 1.0 \cdot 1.00 \cdot \left(\frac{385}{350}\right)^{1.10} \cdot 8 \cdot 180 \cdot \frac{0.8}{1.30} = 12892 \text{ N}$$

determination of the design value of the screw tension resistance:

$$F_{tens,d} = \frac{F_{tens,k}}{\gamma_{M2}}$$

$$F_{tens,k} = 24100 \text{ N (acc. to ETA-22/0789:2023, table A6.1)}$$

$$\gamma_{M2} = 1.25 \text{ (for steel tension failure acc. to EN 1993-1-1:2014, section 6.1)}$$

$$F_{tens,d} = \frac{24100}{1.25} = 19280 \text{ N}$$

design value of the single screw

$$F_{ax,Rd} = \min \left\{ \begin{array}{l} \max \left\{ \begin{array}{l} F_{head,Rd,1} \\ F_{ax,Rd,1} \end{array} \right\} \\ F_{ax,Rd,2} \\ F_{tens,d} \end{array} \right\} = \min \left\{ \begin{array}{l} \max \left\{ \begin{array}{l} 1853 \text{ N} \\ 12834 \text{ N} \end{array} \right\} \\ 12892 \text{ N} \\ 19280 \text{ N} \end{array} \right\} = 12834 \text{ N}$$

determination of the connection resistance

The load-bearing capacity must be reduced by 50 % as only one screw is applied in the connection (see ETA-22/0789:2023 section 2.2)

$$F_{Rd} = \frac{F_{ax,Rd}}{2} = \frac{12834 \text{ N}}{2} = 6417 \text{ N}$$

verification

$$F_{Ed} \leq F_{Rd}$$

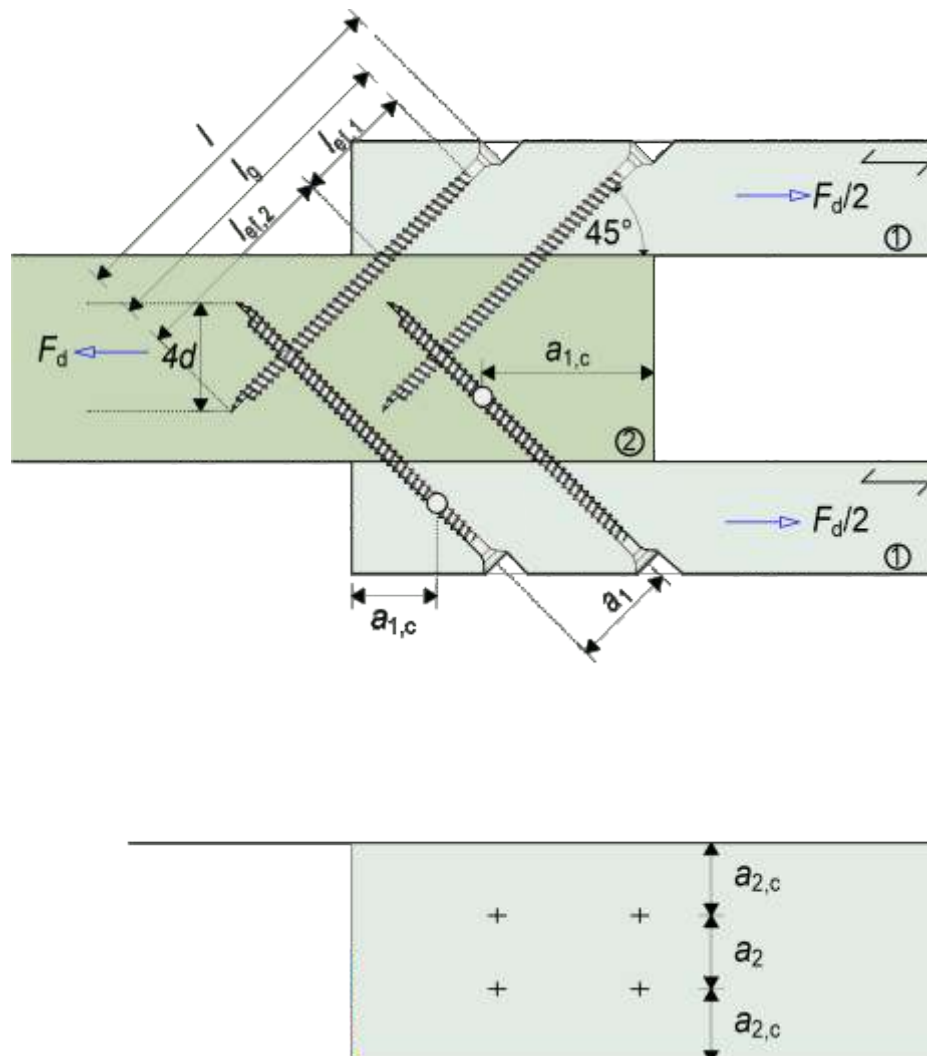
$$5250 \text{ N} \leq 6417 \text{ N}$$

verification fulfilled (82%)

If the connection is designed as suspended construction and the screw penetrates the element 2 less than 70 % of its height, the load-bearing capacity in tension perpendicular-to-grain of element 2 must be verified.

FULLY THREADED SCREWS LOADED IN TENSION

A.1.1.2 tension lap joint with inclined screws

**DETAILS**

service class SC1

loading $F_{Ed} = 40 \text{ kN}$

(category A, duration of load medium-term)

construction elements

construction element 1: laminated veneer beech lumber

 $\rho_k = 730 \text{ kg/m}^3$, $t_1 = 60 \text{ mm}$ construction element 2: solid timber C24, $t_2 = 120 \text{ mm}$ Wood Screw C-FT-8x200/190 $d = 8 \text{ mm}$, $l = 200 \text{ mm}$, $l_g = 190 \text{ mm}$ $l_{ef,1} = 75 \text{ mm}$, $l_{ef,2} = 115 \text{ mm}$, $d_h = 15 \text{ mm}$, pre-drilled laminated veneer lumber made of beech

TIMBER-TO-TIMBER CONNECTION CALCULATION EXAMPLE

minimum spacing

(acc. to ETA-22/0789:2023, table A6.4)

$$a_1 = 40 \text{ mm} \geq 5 \cdot d = 5 \cdot 8 = 40 \text{ mm} \rightarrow \text{OK}$$

$$a_{1,c} = 50 \text{ mm} \geq 5 \cdot d = 5 \cdot 8 = 40 \text{ mm} \rightarrow \text{OK}$$

$$a_2 = 40 \text{ mm} \geq 2.5 \cdot d = 2.5 \cdot 8 = 20 \text{ mm} \rightarrow \text{OK}$$

$$a_{2,c} = 40 \text{ mm} \geq 4 \cdot d = 4 \cdot 8 = 32 \text{ mm} \rightarrow \text{OK}$$

de termination of the load bearing capacity of the single screw

$$F_{ax,Rd} = \min \left\{ \begin{array}{l} \max \left\{ \begin{array}{l} \text{head pull-through resistance in element 1} \\ \text{withdrawal resistance in element 1} \end{array} \right\} \\ \text{withdrawal resistance in element 2} \\ \text{screw tension resistance} \end{array} \right\}$$

design value of the head pull-through resistance in element 1:

$$F_{head,Rd,1} = f_{head,k} \cdot d_h^2 \cdot \left(\frac{\rho_k}{350} \right)^{0.8} \cdot \frac{k_{mod}}{\gamma_M}$$

$f_{head,k}$ 12.4 N/mm² (acc. to ETA- 22/0789:2023, table A6.7)

ρ_k 730 kg/m³ characteristic density of the timber element

k_{mod} 0.8 (SC1, duration of load medium-term)

γ_M 1.30 (for connections in timber construction acc. to EN 1995-1-1, table 2.3)

$$F_{head,Rd,1} = 12.4 \cdot 15^2 \cdot \left(\frac{730}{350} \right)^{0.8} \cdot \frac{0.8}{1.30} = 3091 \text{ N}$$

design value of the withdrawal resistance in element 1:

$$F_{ax,45,Rd,1} = f_{ax,k,90} \cdot k_{ax} \cdot k_{sys} \cdot \left(\frac{\rho_k}{\rho_{k,ref}} \right)^{k_p} \cdot d \cdot l_{ef,1} \cdot \frac{k_{mod}}{\gamma_M}$$

$f_{ax,k,90}$ 13.1 N/mm² (acc. to ETA- 22/0789:2023, table A6.1)

k_{ax} 1.0 for $30^\circ \leq \alpha \leq 90^\circ$

k_{sys} 1.0 for laminated veneer lumber

ρ_k 730 kg/m³ characteristic density of the timber raw material

$\rho_{k,ref}$ 350 kg/m³ reference characteristic density of the timber raw material

k_p 1.70 for diffuse porous hardwood and $0^\circ \leq \alpha \leq 90^\circ$

$l_{ef,1}$ 75 mm

k_{mod} 0.8 (SC1, duration of load medium-term)

γ_M 1.30 (for connections in timber construction acc. to EN 1995-1-1, table 2.3)

FULLY THREADED SCREWS LOADED IN TENSION

A.1.1.2 tension lap joint with inclined screws

$$F_{ax,45,Rd,1} = 13.1 \cdot 1.0 \cdot 1.0 \cdot \left(\frac{730}{350} \right)^{1.70} \cdot 8 \cdot 75 \cdot \frac{0.8}{1.30} = 16877 \text{ N}$$

design value of the withdrawal resistance in element 2:

$$F_{ax,45,Rd,2} = f_{ax,k,90} \cdot k_{ax} \cdot k_{sys} \cdot \left(\frac{\rho_k}{\rho_{k,ref}} \right)^{kp} \cdot d \cdot l_{ef,2} \cdot \frac{k_{mod}}{\gamma_M}$$

$f_{ax,k,90}$ 13.1 N/mm² (acc. to ETA- 22/0789:2023, table A6.1)

k_{ax} 1.0 for $30^\circ \leq \alpha \leq 90^\circ$

k_{sys} 1.0 for solid timber

k_p 1.10 for softwood and $15^\circ \leq \alpha \leq 90^\circ$

ρ_k 350 kg/m³ characteristic density of the timber raw material

$l_{ef,2}$ 115 mm

$$F_{ax,45,Rd,2} = 13.1 \cdot 1.0 \cdot 1.0 \cdot \left(\frac{350}{350} \right)^{1.10} \cdot 8 \cdot 115 \cdot \frac{0.8}{1.30} = 7417 \text{ N}$$

design value of the screw tension resistance:

$$F_{tens,d} = \frac{F_{tens,k}}{\gamma_{M2}}$$

$F_{tens,k}$ 24100 N (acc. to ETA- 22/0789:2023, table A6.1)

γ_{M2} 1.25 (for steel tension failure acc. to EN 1993-1-1:2014, section 6.1)

$$F_{tens,d} = \frac{24100}{1.25} = 19280 \text{ N}$$

$$F_{ax,Rd} = \min \left\{ \begin{array}{l} \max \left\{ \begin{array}{l} F_{head,Rd,1} \\ F_{ax,Rd,1} \end{array} \right\} \\ F_{ax,Rd,2} \\ F_{tens,d} \end{array} \right\} = \min \left\{ \begin{array}{l} \max \left\{ \begin{array}{l} 3091 \text{ N} \\ 16877 \text{ N} \end{array} \right\} \\ 7417 \text{ N} \\ 19280 \text{ N} \end{array} \right\} = 7417 \text{ N}$$

TIMBER-TO-TIMBER CONNECTION CALCULATION EXAMPLE

determination of the connection resistance

$$F_{ax,Rd} = n_{ef} \cdot F_{ax,Rd} \cdot (\cos \alpha + \mu \cdot \sin \alpha)$$

$$n_{ef} = \max \left\{ \frac{n^{0.9}}{0.9 \cdot n} \right\} = \max \left\{ \frac{8^{0.9}}{0.9 \cdot 8} \right\} = \max \left\{ \frac{6.5}{7.2} \right\} = 7.2$$

μ 0.3 friction coefficient between the timber members (acc. to ETA-22/0789:2023, section A7.1)

$$F_{ax,Rd} = 7.2 \cdot 7417 \cdot (\cos(45) + 0.3 \cdot \sin(45)) = 49087 \text{ N}$$

verification

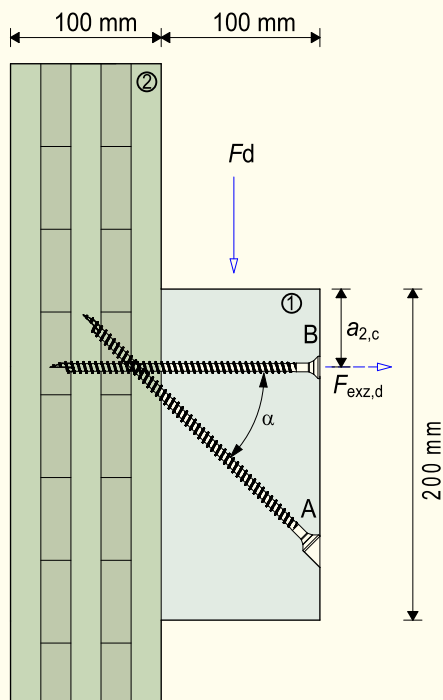
$$F_{E,d} \leq F_{ax,Rd}$$

$$40000 \text{ N} \leq 49087 \text{ N}$$

verification fulfilled (81 %)

FULLY THREADED SCREWS LOADED IN TENSION

A.1.1.3 CLT – solid timber ledger



DETAILS

service class SC1

loading

$$F_{Ed} = 5.0 \text{ kN} \equiv 5000 \text{ N}$$

(category A, duration of load medium-term)

construction elements

construction element 1: solid timber C24

construction element 2: CLT

screw

A: Wood Screw C-FT-8x220/210

$$d = 8 \text{ mm}, l = 220 \text{ mm}, l_{ef,1} = 103 \text{ mm},$$

$$l_{ef,2} = 107 \text{ mm}$$

B: Wood Screw C-FT-8x160/150

$$d = 8 \text{ mm}, l = 160 \text{ mm}, l_{ef,1} = 90 \text{ mm},$$

$$l_{ef,2} = 60 \text{ mm}$$

minimum spacing screw B

(acc. to ETA-22/0789:2023 table A6.4)

$$a_{2,c} = 40 \text{ mm} \geq 4 \cdot d = 4 \cdot 8 = 32 \text{ mm} \rightarrow \text{OK}$$

action design value

screw A transfers the vertical force (mainly axially).

 screw B transfers the moment tension force $F_{exz,d}$ resulting from the eccentric load application. In a simplified assumption, the height of the compressive stress block is taken to be 20 mm.

$$F_{exz,d} = \frac{F_{Ed} \cdot 0.5 \cdot b_{ST}}{h_{ST} - a_{2,c} - 2/3 \cdot 20} = \frac{F_{Ed} \cdot 0.5 \cdot 100}{200 - 40 - 2/3 \cdot 20} = 1705 \text{ N}$$

determination of the load bearing capacity of the screw A

$$F_{ax,Rd} = \min \left\{ \begin{array}{l} \text{withdrawal resistance in element 1} \\ \text{withdrawal resistance in element 2} \\ \text{screw tension resistance} \end{array} \right\}$$

design value of the withdrawal resistance in element 1:

$$F_{ax,45,Rd,A1} = f_{ax,k,90} \cdot k_{ax} \cdot k_{sys} \cdot \left(\frac{\rho_k}{\rho_{k,ref}} \right)^{k_p} \cdot d \cdot l_{ef,1} \cdot \frac{k_{mod}}{\gamma_M}$$

$$f_{ax,k,90} \quad 13.1 \text{ N/mm}^2 \text{ (acc. to ETA-22/0789:2023, table A6.1)}$$

$$k_{ax} \quad 1.0 \text{ for } 30^\circ \leq \alpha \leq 90^\circ$$

$$k_{sys} \quad 1.00 \text{ for solid timber}$$

$$\rho_k \quad 350 \text{ kg/m}^3 \text{ characteristic density of the timber raw material}$$

TIMBER-TO-TIMBER CONNECTION CALCULATION EXAMPLE

- $\rho_{k,ref}$ 350 kg/m³ reference characteristic density of the timber raw material
 k_p 1.10 for softwood and $15^\circ \leq \alpha \leq 90^\circ$
 $l_{ef,1}$ 103 mm
 k_{mod} 0.8 (SC1, duration of load medium-term)
 γ_M 1.30 (for connections in timber construction acc. to EN 1995-1-1, table 2.3)

$$F_{ax,45,Rd,A1} = 13.1 \cdot 1.0 \cdot 1.00 \cdot \left(\frac{350}{350}\right)^{1.10} \cdot 8 \cdot 103 \cdot \frac{0.8}{1.30} = 6643 \text{ N}$$

design value of the withdrawal resistance in element 2:

$$F_{ax,45,Rd,A2} = f_{ax,k,90} \cdot k_{ax} \cdot k_{sys} \cdot \left(\frac{\rho_k}{\rho_{k,ref}}\right)^{k_p} \cdot d \cdot l_{ef,2} \cdot \frac{k_{mod}}{\gamma_M}$$

- $f_{ax,k,90}$ 13.1 N/mm² (acc. to ETA-22/0789:2023, table A6.1)
 k_{ax} 1.0 for $30^\circ \leq \alpha \leq 90^\circ$
 k_{sys} 1.10 for 3 penetrated layers (acc. to ETA-22/0789:2023, table A6.6)
 ρ_k 350 kg/m³ characteristic density of the timber raw material
 k_p 1.10 for softwood and $15^\circ \leq \alpha \leq 90^\circ$
 $l_{ef,2}$ 107 mm
 $F_{ax,45,Rd,A2} = 13.1 \cdot 1.0 \cdot 1.10 \cdot \left(\frac{350}{350}\right)^{1.10} \cdot 8 \cdot 107 \cdot \frac{0.8}{1.30} = 7591 \text{ N}$

design value of the screw tension resistance:

$$F_{tens,d} = \frac{F_{tens,k}}{\gamma_{M2}} = \frac{24100}{1.25} = 19280 \text{ N}$$

- $F_{tens,k}$ 24100 N (acc. to ETA-22/0789:2023, table A6.1)
 γ_{M2} 1.25 (for steel tension failure acc. to EN 1993-1-1:2014, section 6.1)

determination of the vertical component:

$$F_{ax,45,Rd,A} = \min \left\{ \begin{array}{l} F_{ax,45,Rd,A1} \\ F_{ax,45,Rd,A2} \\ F_{tens,d,A} \end{array} \right\} = \min \left\{ \begin{array}{l} 6643 \\ 7591 \\ 19280 \end{array} \right\} = 6643 \text{ N}$$

$$F_{Rd,A} = F_{ax,45,Rd,A} \cdot (\cos \alpha + \mu \cdot \sin \alpha)$$

- μ 0.3 friction coefficient between the timber members (acc. to ETA-22/0789:2023, section A.7.1)
 $F_{Rd,A} = 6643 \cdot (\cos 45 + 0.3 \cdot \sin 45) = 6106 \text{ N}$

FULLY THREADED SCREWS LOADED IN TENSION

A.1.1.3 CLT – solid timber ledger

verification screw A

$$F_{Ed} \leq F_{Rd,A}$$

$$5000 \text{ N} \leq 6106 \text{ N}$$

verification fulfilled (82 %)

determination of the load bearing capacity of the screw B

$$F_{ax,Rd} = \min \left\{ \begin{array}{l} \text{withdrawal resistance in element 1} \\ \text{withdrawal resistance in element 2} \\ \text{screw tension resistance} \end{array} \right\}$$

design value of the withdrawal resistance in element 1:

$$F_{ax,45,Rd,B1} = f_{ax,k,90} \cdot k_{ax} \cdot k_{sys} \cdot \left(\frac{\rho_k}{\rho_{k,ref}} \right)^{k_p} \cdot d \cdot l_{ef,1} \cdot \frac{k_{mod}}{\gamma_M}$$

$f_{ax,k,90}$ 13.1 N/mm² (acc. to ETA-22/0789:2023 table A6.1)

k_{ax} 1.0 for $30^\circ \leq \alpha \leq 90^\circ$

k_{sys} 1.00 for solid timber

ρ_k 350 kg/m³ characteristic density of the timber raw material

$\rho_{k,ref}$ 350 kg/m³ reference characteristic density of the timber raw material

k_p 1.10 for softwood and $15^\circ \leq \alpha \leq 90^\circ$

$l_{ef,1}$ 90 mm

k_{mod} 0.8 (SC1, duration of load medium-term)

γ_M 1.30 (for connections in timber construction acc. to EN 1995-1-1, table 2.3)

design value of the withdrawal resistance in element 2:

$$F_{ax,45,Rd,B2} = f_{ax,k,90} \cdot k_{ax} \cdot k_{sys} \cdot \left(\frac{\rho_k}{\rho_{k,ref}} \right)^{k_p} \cdot d \cdot l_{ef,2} \cdot \frac{k_{mod}}{\gamma_M}$$

$f_{ax,k,90}$ 13.1 N/mm² (acc. to ETA-22/0789:2023, table A6.1)

k_{ax} 1.0 for $30^\circ \leq \alpha \leq 90^\circ$

k_{sys} 1.10 for 3 penetrated layers (acc. to ETA-22/0789:2023, table A6.6)

ρ_k 350 kg/m³ characteristic density of the timber raw material

k_p 1.10 for softwood and $15^\circ \leq \alpha \leq 90^\circ$

$l_{ef,2}$ 60 mm

$$F_{ax,45,Rd,B2} = 13.1 \cdot 1.0 \cdot 1.10 \cdot \left(\frac{350}{350} \right)^{1.10} \cdot 8 \cdot 60 \cdot \frac{0,8}{1.30} = 4256 \text{ N}$$

TIMBER-TO-TIMBER CONNECTION CALCULATION EXAMPLE

design value of the screw tension resistance:

$$F_{\text{tens,d}} = \frac{F_{\text{tens,k}}}{\gamma_{M2}} = \frac{24100}{1.25} = 19280 \text{ N}$$

$F_{\text{tens,k}}$ 24100 N (acc. to ETA- 22/0789:2023, table A6.1)

γ_{M2} 1.25 (for steel tension failure acc. to EN 1993-1-1:2014, section 6.1)

$$F_{\text{ax,45,Rd,B}} = \min \left\{ \begin{array}{l} F_{\text{ax,45,Rd,B1}} \\ F_{\text{ax,45,Rd,B2}} \\ F_{\text{tens,d,B}} \end{array} \right\} = \min \left\{ \begin{array}{l} 5804 \\ 4256 \\ 19280 \end{array} \right\} = 4256 \text{ N}$$

verification screw B

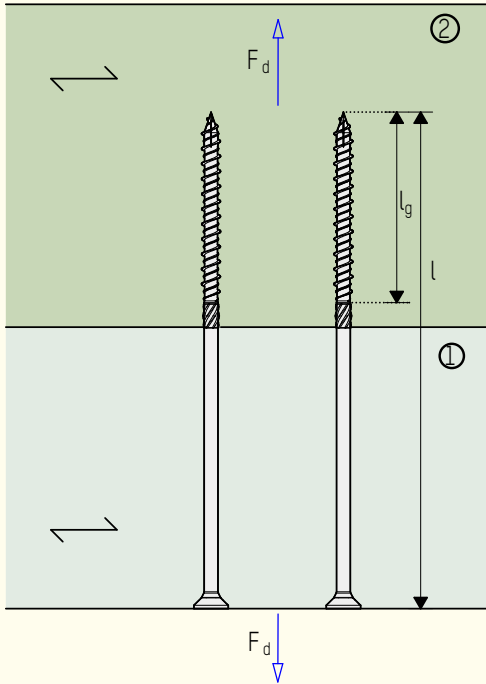
$$F_{\text{Ed}} \leq F_{\text{Rd,B}}$$

$$1705 \text{ N} \leq 4256 \text{ N}$$

verification fulfilled (40 %)

PARTIALLY THREADED SCREWS LOADED IN TENSION

A.1.2.1 general – connection between two timber elements



DETAILS

service class SC1

loading

permanent load: $F_{G,k} = 1.00$ kN

variable load: $F_{N,k} = 1.25$ kN

(category A, duration of load medium-term)

construction elements

construction element 1:

glue laminated timber GL24h

construction element 2:

solid timber C24

Wood Screw C-PT-8x260/100

2 screws, $d = 8$ mm, $l = 260$ mm,

$l_g = l_{ef} = 100$ mm, $d_h = 15$ mm

action design value

$$F_{Ed} = \gamma_G \cdot F_{G,k} + \gamma_Q \cdot F_{N,k} =$$

$$1.35 \cdot 1.00 + 1.5 \cdot 1.25 = 3.225 \text{ kN} \triangleq 3225 \text{ N}$$

determination of the load bearing capacity of the single screw

$$F_{ax,Rd} = \min \left\{ \begin{array}{l} \text{head pull-through resistance in element 1} \\ \text{withdrawal resistance in element 2} \\ \text{screw tension resistance} \end{array} \right\}$$

design value of the head pull-through resistance in element 1:

$$F_{head,Rd,1} = f_{head,k} \cdot d_h^2 \cdot \left(\frac{\rho_k}{350} \right)^{0.8} \cdot \frac{k_{mod}}{\gamma_M}$$

$f_{head,k}$ 12.4 N/mm² (acc. to ETA- 22/0789:2023, table A6.7)

ρ_k 730 kg/m³ characteristic density of the timber element

k_{mod} 0.8 (SC1, duration of load medium-term)

γ_M 1.30 (for connections in timber construction acc. to EN 1995-1-1, table 2.3)

TIMBER-TO-TIMBER CONNECTION CALCULATION EXAMPLE

design value of the withdrawal resistance in element 2:

$$F_{ax,Rd,2} = f_{ax,k,90} \cdot k_{ax} \cdot k_{sys} \cdot \left(\frac{\rho_k}{\rho_{k,ref}} \right)^{k_p} \cdot d \cdot l_{ef} \cdot \frac{k_{mod}}{\gamma_M}$$

$$f_{ax,k,90} \quad 10.9 \text{ N/mm}^2 \text{ (acc. to ETA-22/0789:2023, table A6.2)}$$

$$k_{ax} \quad 1.0 \text{ for } 30^\circ \leq \alpha \leq 90^\circ$$

$$k_{sys} \quad 1.0 \text{ for solid timber}$$

$$\rho_k \quad 350 \text{ kg/m}^3 \text{ characteristic density of the timber raw material}$$

$$\rho_{k,ref} \quad 350 \text{ kg/m}^3 \text{ reference characteristic density of the timber raw material}$$

$$k_p \quad 1.10 \text{ for softwood and } 15^\circ \leq \alpha \leq 90^\circ$$

$$l_{ef} \quad 100 \text{ mm}$$

$$F_{ax,Rd,2} = 10.9 \cdot 1.0 \cdot 1.00 \cdot \left(\frac{350}{350} \right)^{1.10} \cdot 8 \cdot 100 \cdot \frac{0.8}{1.30} = 5366 \text{ N}$$

design value of the screw tension resistance:

$$F_{tens,d} = \frac{F_{tens,k}}{\gamma_{M2}}$$

$$F_{tens,k} \quad 23300 \text{ N (acc. to ETA-22/0789:2023, table A6.1)}$$

$$\gamma_{M2} \quad 1.25 \text{ (for steel tension failure acc. to EN 1993-1-1:2014, section 6.1)}$$

$$F_{tens,d} = \frac{23300}{1.25} = 18640 \text{ N}$$

$$F_{ax,Rd} = \min \left\{ \begin{array}{l} F_{head,Rd,1} \\ F_{ax,Rd,2} \\ F_{tens,d} \end{array} \right\} = \min \left\{ \begin{array}{l} 1853 \text{ N} \\ 5366 \text{ N} \\ 18640 \text{ N} \end{array} \right\} = 1853 \text{ N}$$

determination of the connection resistance

$$F_{Rd} = n_{ef} \cdot F_{ax,Rd}$$

$$n_{ef} = n^{0.9} = 2^{0.9} = 1.87$$

$$F_{Rd} = 1.87 \cdot 1853 = 3458 \text{ N}$$

verification

$$F_{Ed} \leq F_{Rd}$$

$$3225 \text{ N} \leq 3458 \text{ N}$$

verification fulfilled (93 %)

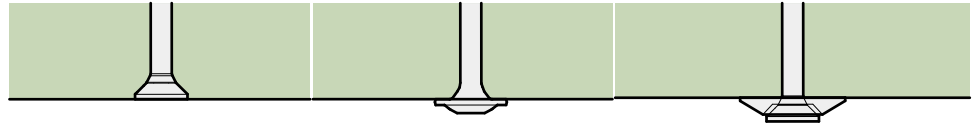
If the connection is designed as suspended construction and the screw penetrates the element 2 less than 70 % of its height, the load-bearing capacity in tension perpendicular-to-grain of element 2 must be verified.

PARTIALLY THREADED SCREWS LOADED IN TENSION

A.1.2.1 general – connection between two timber elements

comparison of the load bearing capacity of different head types

countersunk head washer head countersunk head with washer type M



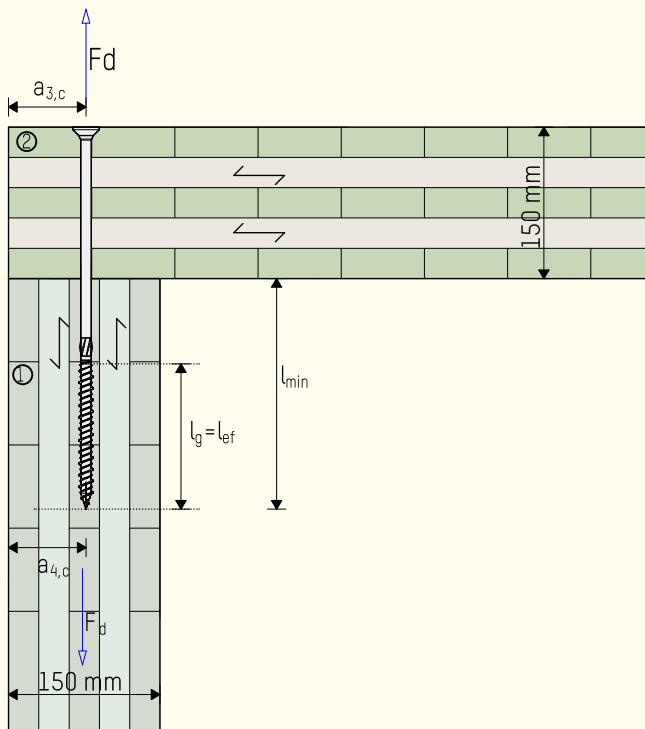
d_h [mm]	15	20	28
$f_{head,k}$ [N/mm ²] acc. to ETA-22/0789:2023, table A6.7 and A6.8)	12.4	17.6	13.7 ¹⁾
$F_{head,Rd,1}$ [N]	1853	4676	7133

¹⁾ according to Declaration of Performance DoP-220789



PARTIALLY THREADED SCREWS LOADED IN TENSION

A.1.2.2 CLT-floor-wall-joint



DETAILS

service class SC1

loading

$F_{Ed} = 1.5$ kN each screw
(duration of load short-term / instantaneous according to EN1995-1-1:2005)

construction elements

construction element 1 and 2: cross laminated timber

$t = 150$ mm, $\rho_k = 385$ kg/m³

Wood Screw C-PT-8x240/100

$d = 8$ mm, $l = 240$ mm,

$l_g = l_{ef} = 100$ mm, $d_k = 15$ mm

minimum spacing

(acc. to ETA-22/0789:2023, table A6.5)

narrow face: $a_{4,c} = 75$ mm $\geq 3 \cdot d = 3 \cdot 8 = 24$ mm \rightarrow OK

wide face: $a_{3,c} = 75$ mm $\geq 6 \cdot d = 6 \cdot 8 = 48$ mm \rightarrow OK

narrow face: $t_2 \hat{=} l_{min} = 90$ mm $\geq 10 \cdot d = 10 \cdot 8 = 80$ mm \rightarrow OK

determination of the load bearing capacity of the single screw

$$F_{ax,Rd} = \min \left\{ \begin{array}{l} \text{head pull-through resistance in element 1} \\ \text{withdrawal resistance in element 2} \\ \text{screw tension resistance} \end{array} \right\}$$

design value of the head pull-through resistance in element 1:

$$F_{head,Rd,1} = f_{head,k} \cdot d_h^2 \cdot \left(\frac{\rho_k}{350} \right)^{0.8} \cdot \frac{k_{mod}}{\gamma_M}$$

$f_{head,k}$ 12.4 N/mm² (acc. to ETA-22/0789:2023 table A6.7)

ρ_k 385 kg/m³ characteristic density of the timber element

k_{mod} 0.9 (SC1, duration of load short-term according to EN 1995-1-1:2005)

γ_M 1.30 (for connections in timber construction acc. to EN 1995-1-1, table 2.3)

$$F_{head,Rd,1} = 12.4 \cdot 15^2 \cdot \left(\frac{385}{350} \right)^{0.8} \cdot \frac{0.9}{1.30} = 2084 \text{ N}$$

TIMBER-TO-TIMBER CONNECTION CALCULATION EXAMPLE

design value of the withdrawal resistance in element 2:

$$F_{ax,Rd,2} = f_{ax,k,90} \cdot k_{ax} \cdot k_{sys} \cdot \left(\frac{\rho_k}{\rho_{k,ref}} \right)^{k_p} \cdot d \cdot l_{ef} \cdot \frac{k_{mod}}{\gamma_M}$$

$f_{ax,k,90}$ 10.9 N/mm² (acc. to ETA- 22/0789:2023, table A6.2)

k_{ax} 1.0 for $30^\circ \leq \alpha \leq 90^\circ$

k_{sys} 1.13 for 5 penetrated layers (acc. to ETA- 22/0789:2023, table A6.6)

ρ_k 350 kg/m³ characteristic density of the timber raw material

$\rho_{k,ref}$ 350 kg/m³ reference characteristic density of the timber raw material

k_p 0.85 for softwood and $0^\circ \leq \alpha \leq 90^\circ$

l_{ef} 150 mm

$$F_{ax,Rd,2} = 10.9 \cdot 1.0 \cdot 1.13 \cdot \left(\frac{385}{350} \right)^{0.85} \cdot 8 \cdot 100 \cdot \frac{0.9}{1.30} = 7397 \text{ N}$$

design value of the screw tension resistance

$$F_{tens,d} = \frac{F_{tens,k}}{\gamma_{M2}}$$

$F_{tens,k}$ 24100 N (acc. to ETA-22/0789:2023, table A6.1)

γ_{M2} 1.25 (for steel tension failure acc. to EN 1993-1-1:2014, section 6.1)

$$F_{tens,d} = \frac{2410}{1.25} = 19280 \text{ N}$$

$$F_{ax,Rd} = \min \left\{ \begin{array}{l} F_{head,Rd,1} \\ F_{ax,Rd,2} \\ F_{tens,d} \end{array} \right\} = \min \left\{ \begin{array}{l} 2084 \text{ N} \\ 7397 \text{ N} \\ 19280 \text{ N} \end{array} \right\} = 2084 \text{ N}$$

verification

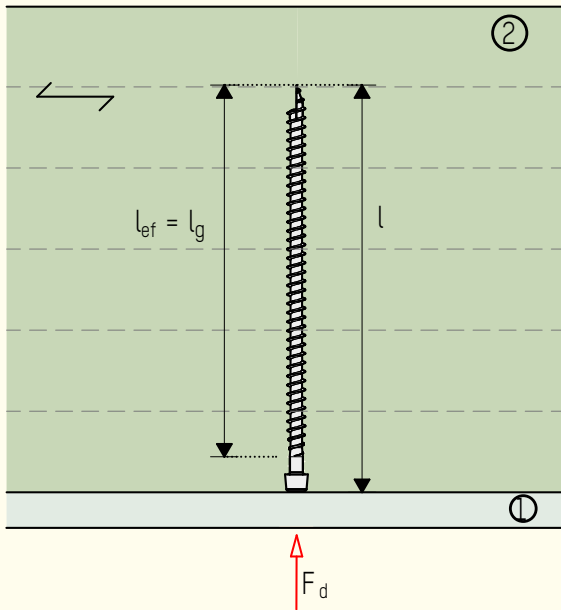
$$F_{Ed} \leq F_{Rd}$$

$$1500 \text{ N} \leq 2084 \text{ N}$$

verification fulfilled (72 %)

FULLY THREADED SCREWS LOADED IN COMPRESSION

A.1.3.1 general – fully threaded screw



DETAILS

service class SC1

loadingpermanent load: $F_{G,k} = 2.50$ kNvariable load: $F_{N,k} = 3.35$ kN

(category A, duration of load medium-term)

construction elements

glue laminated timber GL24h

Wood Screw CY-FT-10x260/248 $d = 10$ mm, $d_i = 6.2$ mm, $l = 260$ mm, $l_g = l_{ef} = 248$ mmaction design value

$$F_{Ed} = \gamma_G \cdot F_{G,k} + \gamma_Q \cdot F_{N,k} =$$

$$1.35 \cdot 2.5 + 1.5 \cdot 3.35 = 8.4 \text{ kN} \triangleq 8400 \text{ N}$$

determination of the load bearing capacity of the single screw

$$F_{ax,Rd} = \min \left\{ \begin{array}{l} \text{withdrawal or push-in resistance} \\ \text{buckling resistance} \end{array} \right\}$$

design value of the withdrawal resistance (pushing in):

$$F_{ax,Rd} = f_{ax,k,90} \cdot k_{ax} \cdot k_{sys} \cdot \left(\frac{\rho_k}{\rho_{k,ref}} \right)^{k_p} \cdot d \cdot l_{ef} \cdot \frac{k_{mod}}{\gamma_M}$$

 $f_{ax,k,90}$ 12.5 N/mm² (acc. to ETA-22/0789:2023, table A6.1) k_{ax} 1.0 for $30^\circ \leq \alpha \leq 90^\circ$ k_{sys} 1.13 for 5 penetrated layers (acc. to ETA-22/0789:2023, table A6.6) ρ_k 350 kg/m³ characteristic density of the timber raw material $\rho_{k,ref}$ 350 kg/m³ reference characteristic density of the timber raw material k_p 1.10 for softwood and $15^\circ \leq \alpha \leq 90^\circ$ $l_{ef,1}$ 248 mm k_{mod} 0.8 (SC1, duration of load medium-term) γ_M 1.30 (for connections in timber construction acc. to EN 1995-1-1, table 2.3)

$$F_{ax,Rd} = 12.5 \cdot 1.0 \cdot 1.13 \cdot \left(\frac{350}{350} \right)^{1.10} \cdot 10 \cdot 248 \cdot \frac{0.8}{1.30} = 21557 \text{ N}$$

STEEL-TO-TIMBER CONNECTION CALCULATION EXAMPLE



design value of the buckling resistance:

$$F_{ki,Rd} = \kappa_c \cdot \frac{N_{pl,k}}{\gamma_{M1}}$$

$$f_{y,k} = 950 \text{ N/mm}^2 \text{ acc. ETA-22/0789:2023, table A6.1}$$

$$N_{ki,k} = \sqrt{c_h \cdot E_s \cdot I_s} = \sqrt{119.35 \cdot 210000 \cdot 72.53} = 42636 \text{ N}$$

$$c_h = (0.19 + 0.012 \cdot d) \cdot \rho_k \cdot \left(\frac{90 + \alpha}{180} \right) = (0.19 + 0.012 \cdot 10) \cdot 385 \cdot \left(\frac{90 + 90}{180} \right) = 119.35 \text{ N/mm}^2$$

$$E_s = 210\,000 \text{ N/mm}^2 \text{ acc. ETA-22/0789:2023, table A6.1}$$

$$I_s = \frac{\pi \cdot d_i^4}{64} = \frac{\pi \cdot 6.2^4}{64} = 72.53 \text{ mm}^4$$

$$\gamma_{M1} = 1.00 \text{ (for stability failure of steel elements acc. EN 1993-1-1:2014, section 6.1)}$$

$$F_{ki,Rd} = 0.65 \cdot \frac{28681}{1.00} = 18634 \text{ N}$$

$$F_{ax,Rd} = \min \left\{ \begin{array}{l} F_{ax,Rd} \\ F_{ki,Rd} \end{array} \right\} = \min \left\{ \begin{array}{l} 21557 \\ 18634 \end{array} \right\} = 18634 \text{ N}$$

determination of the connection resistance

The load-bearing capacity must be reduced by 50 % as only one screw is applied in the connection (see ETA-22/0789:2023, section 2.2)

$$F_{Rd} = \frac{F_{ax,Rd}}{2} = \frac{18634 \text{ N}}{2} = 9317 \text{ N}$$

verification

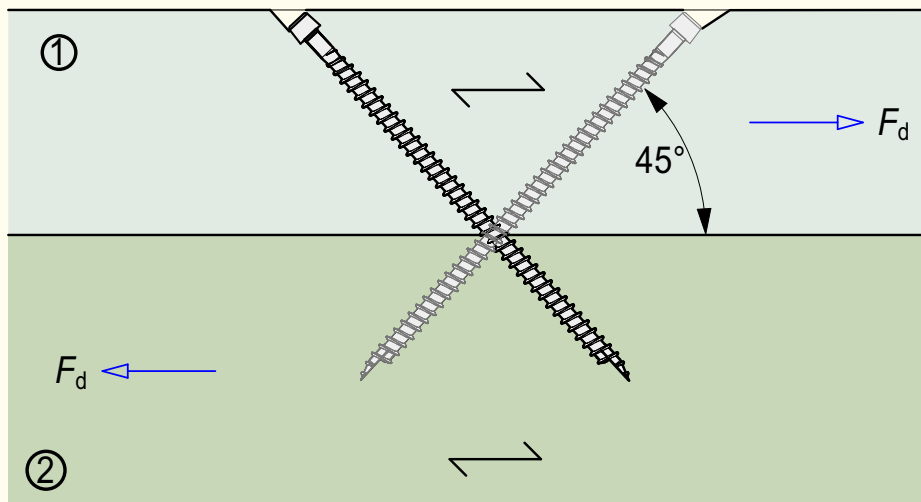
$$F_{Ed} \leq F_{Rd}$$

$$8400 \text{ N} \leq 9317 \text{ N}$$

verification fulfilled (90 %)

FULLY THREADED SCREWS LOADED IN COMPRESSION

A.1.3.2 screw cross – single shear connection

**DETAILS**

service class SC1

loading

permanent load: $F_{G,k} = 2.85 \text{ kN}$

variable load: $F_{N,k} = 4.10 \text{ kN}$

(category A, duration of load medium-term)

construction elements

construction elements 1 and 2:

solid timber, C24

Wood Screw CY-FT-8x260

(1 screw cross \equiv 2 screws)

$d = 8 \text{ mm}$, $l = 260 \text{ mm}$, $l_g = 250 \text{ mm}$, $d_i = 5.1 \text{ mm}$

$l_{ef,1} = 136 \text{ mm}$, $l_{ef,2} = 114 \text{ mm}$

TIMBER-TO-TIMBER CONNECTION CALCULATION EXAMPLE

action design value

$$F_{Ed} = \gamma_G \cdot F_{G,k} + \gamma_Q \cdot F_{N,k} =$$

$$1.35 \cdot 2.85 + 1.5 \cdot 4.10 = 9.998 \text{ kN} \approx 9998 \text{ N}$$

determination of the load bearing capacity of the single screw

$$F_{ax,45,Rd} = \min \left\{ \begin{array}{l} \text{withdrawal or pushing in resistance in element (1)} \\ \text{withdrawal or pushing in resistance in element (2)} \\ \text{buckling resistance} \\ \text{screw tension resistance} \end{array} \right\}$$

design value of the withdrawal resistance (pushing in) in element 1:

$$F_{ax,45,Rd,1} = f_{ax,k,90} \cdot k_{ax} \cdot k_{sys} \cdot \left(\frac{\rho_k}{\rho_{k,ref}} \right)^{k_p} \cdot d \cdot l_{ef,1} \cdot \frac{k_{mod}}{\gamma_M}$$

$$f_{ax,k,90} \quad 13.1 \text{ N/mm}^3 \text{ (acc. to ETA- 22/0789:2023, table A6.1)}$$

$$k_{ax} \quad 1.0 \text{ for } 30^\circ \leq \alpha \leq 90^\circ$$

$$k_{sys} \quad 1.00 \text{ for solid timber}$$

$$\rho_k \quad 350 \text{ kg/m}^3 \text{ characteristic density of the timber raw material}$$

$$\rho_{k,ref} \quad 350 \text{ kg/m}^3 \text{ reference characteristic density of the timber raw material}$$

$$k_p \quad 1.10 \text{ for softwood and } 15^\circ \leq \alpha \leq 90^\circ$$

$$l_{ef,1} \quad 136 \text{ mm}$$

$$k_{mod} \quad 0.8 \text{ (SC1, duration of load medium-term)}$$

$$\gamma_M \quad 1.30 \text{ (for connections in timber construction acc. to EN 1995-1-1, table 2.3)}$$

$$F_{ax,45,Rd,1} = 13.1 \cdot 1.0 \cdot 1.00 \cdot \left(\frac{350}{350} \right)^{1.10} \cdot 8 \cdot 136 \cdot \frac{0.8}{1.30} = 8771 \text{ N}$$

design value of the withdrawal resistance (pushing in) in element 2:

$$F_{ax,45,Rd,2} = f_{ax,k,90} \cdot k_{ax} \cdot k_{sys} \cdot \left(\frac{\rho_k}{\rho_{k,ref}} \right)^{k_p} \cdot d \cdot l_{ef,2} \cdot \frac{k_{mod}}{\gamma_M}$$

$$l_{ef,2} \quad 114 \text{ mm}$$

$$F_{ax,45,Rd,2} = 13.1 \cdot 1.0 \cdot 1.10 \cdot \left(\frac{350}{350} \right)^{1.10} \cdot 8 \cdot 114 \cdot \frac{0.8}{1.30} = 7352$$

design value of the buckling resistance:

$$F_{ki,Rd} = \kappa_c \cdot \frac{N_{pl,k}}{\gamma_{M1}}$$

FULLY THREADED SCREWS LOADED IN COMPRESSION

A.1.3.3 screw cross – single shear connection

$$\kappa_c = \begin{cases} 1.0 & \text{für } \bar{\lambda}_k \leq 0.2 \\ \frac{1.0}{k + \sqrt{k^2 - \bar{\lambda}_k^2}} & \text{für } \bar{\lambda}_k > 0.2 \end{cases} \rightarrow \frac{1.0}{1.10 + \sqrt{1.10^2 - 0.92^2}} = 0.59$$

$$k = 0.5 \cdot \left[1 + 0.49 \cdot (\bar{\lambda}_k - 0.2) + \bar{\lambda}_k^2 \right] = 0.5 \cdot \left[1 + 0.49 \cdot (0.92 - 0.2) + 0.92^2 \right] = 1.10$$

$$\bar{\lambda}_k = \sqrt{\frac{N_{pl,k}}{N_{ki,k}}} = \sqrt{\frac{19407}{22881}} = 0.92$$

$$N_{pl,k} = \frac{\pi \cdot d_i^2}{4} \cdot f_{y,k} = \pi \cdot \frac{5.1^2}{4} \cdot 950 = 19407 \text{ N}$$

$$f_{y,k} = 950 \text{ N/mm}^2 \text{ (acc. to ETA-22/0789:2023, table A6.1)}$$

$$N_{ki,k} = \sqrt{c_h \cdot E_s \cdot I_s} = \sqrt{75.08 \cdot 210000 \cdot 33.2} = 22881 \text{ N}$$

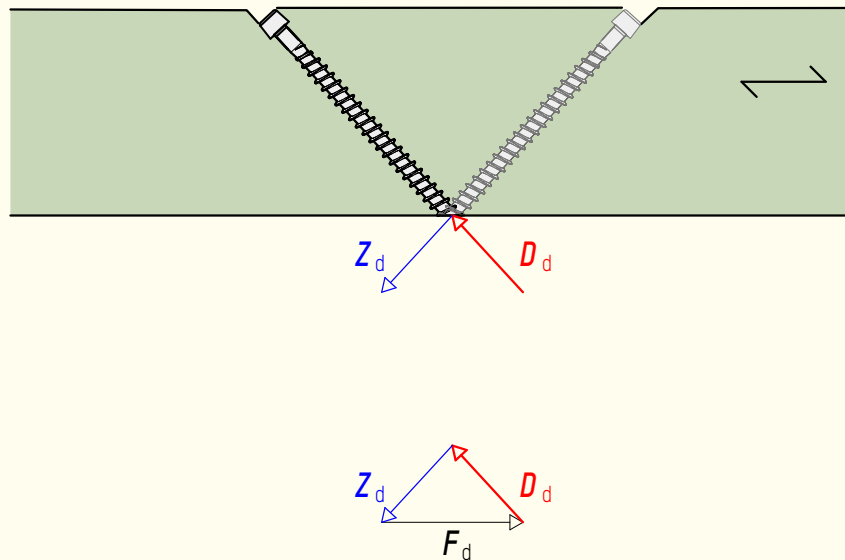
$$c_h = (0.19 + 0.012 \cdot d) \cdot \rho_k \cdot \left(\frac{90 + \alpha}{180} \right) = (0.19 + 0.012 \cdot 8) \cdot 350 \cdot \left(\frac{90 + 45}{180} \right) = 75.08 \text{ N/mm}^2$$

$$E_s = 210\,000 \text{ N/mm}^2 \text{ acc. to ETA-22/0789:2023, table A6.1}$$

$$I_s = \frac{\pi \cdot d^4}{64} = \frac{\pi \cdot 5.1^4}{64} = 33.2 \text{ mm}^2$$

$$\gamma_{M1} = 1.00 \text{ (for stability failure of steel elements acc. to EN 1993-1-1:2014, section 6.1)}$$

$$F_{ki,d} = \kappa_c \cdot \frac{N_{pl,k}}{\gamma_{M1}} = 0.59 \cdot \frac{19407}{1.00} = 11392 \text{ N}$$



TIMBER-TO-TIMBER CONNECTION CALCULATION EXAMPLE

determination of screw tension resistance:

$$F_{\text{tens,d}} = \frac{F_{\text{tens,k}}}{\gamma_{M2}}$$

γ_{M2} 1.25 (for steel tension failure acc. to EN 1993-1-1:2014, section 6.1)

$$F_{\text{tens,d}} = \frac{24100}{1.25} = 19280 \text{ N}$$

design value of load bearing capacity of the single screw:

$$F_{\text{ax,45,Rd}} = \min \left\{ \begin{array}{l} F_{\text{ax,45,Rd,1}} \\ F_{\text{ax,45,Rd,2}} \\ F_{\text{ki,Rd}} \\ F_{\text{tens,d}} \end{array} \right\} = \min \left\{ \begin{array}{l} 8771 \text{ N} \\ 7352 \text{ N} \\ 11392 \text{ N} \\ 19280 \text{ N} \end{array} \right\} = 7352 \text{ N}$$

determination of the connection resistance

$$F_{\text{Rd}} = n_{\text{ef}} \cdot F_{\text{ax,45,Rd}} \cdot \cos(\alpha)$$

n_{ef} 2, $n_{\text{ef}} = n$ for flexible jointing beams (acc. to ETA-22/0789:2023, section A.6.1.1)

$$F_{\text{Rd}} = 2 \cdot 7352 \cdot \cos(45) = 10397 \text{ N}$$

verification

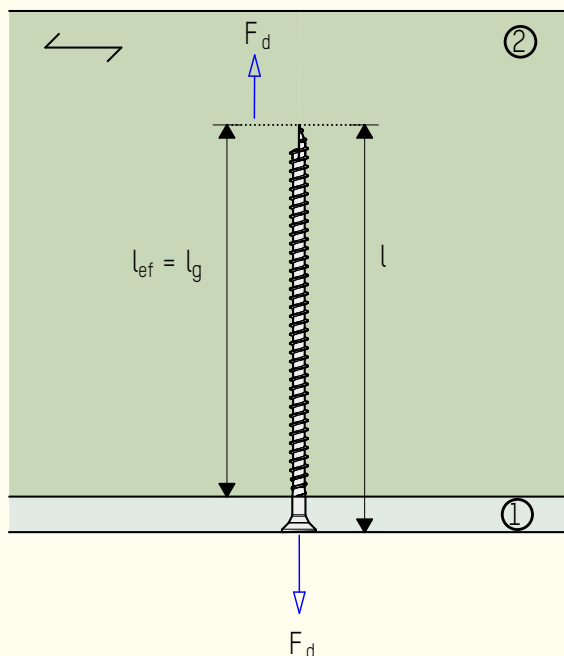
$$F_{\text{Ed}} \leq F_{\text{Rd}}$$

$$9998 \leq 10397$$

verification fulfilled (96 %)

SCREWS LOADED IN TENSION

A.2.1 general – axis-grain-angle 90°



DETAILS

service class SC1

loading

permanent load: $F_{G,k} = 1.80$ kNvariable load: $F_{N,k} = 1.20$ kN

(category A, duration of load medium-term)

construction elements

construction element 1:

steel plate, $t = 10$ mm

construction element 2:

solid timber C24

Wood Screw C-FT-8x240/230

 $d = 8$ mm, $l = 240$ mm, $l_g = l_{ef} = 230$ mmaction design value

$$F_{Ed} = \gamma_G \cdot F_{G,k} + \gamma_Q \cdot F_{N,k} =$$

$$1.35 \cdot 1.80 + 1.5 \cdot 1.20 = 4.23 \text{ kN}$$

determination of the load bearing capacity of the single screw

$$F_{ax,Rd} = \left\{ \begin{array}{l} \text{withdrawal resistance} \\ \text{screw tension resistance} \end{array} \right\}$$

design value of the withdrawal resistance:

$$F_{ax,Rd} = f_{ax,k,90} \cdot k_{ax} \cdot k_{sys} \cdot \left(\frac{\rho_k}{\rho_{k,ref}} \right)^{k_p} \cdot d \cdot l_{ef} \cdot \frac{k_{mod}}{\gamma_M}$$

 $f_{ax,k,90}$ 13.1 N/mm² (acc. to ETA-22/0789:2023, table A6.1) k_{ax} 1.0 for $30^\circ \leq \alpha \leq 90^\circ$ k_{sys} 1.0 for solid timber ρ_k 350 kg/m³ characteristic density of the timber raw material $\rho_{k,ref}$ 350 kg/m³ reference characteristic density of the timber raw material k_p 1.10 for softwood and $15^\circ \leq \alpha \leq 90^\circ$ l_{ef} 230 mm k_{mod} 0.8 (SC1, duration of load medium-term) γ_M 1.30 (for connections in timber construction acc. to EN 1995-1-1, table 2.3)

STEEL-TO-TIMBER CONNECTION CALCULATION EXAMPLE



$$F_{ax,Rd} = 13.1 \cdot 1.0 \cdot 1.10 \cdot \left(\frac{350}{350}\right)^{1.10} \cdot 8 \cdot 230 \cdot \frac{0.8}{1.30} = 14833 \text{ N}$$

design value of the screw tension resistance:

$$F_{tens,d} = \frac{F_{tens,k}}{\gamma_{M2}}$$

$$F_{tens,k} = 24100 \text{ N (acc. to ETA- 22/0789:2023, table A6.1)}$$

$$\gamma_{M2} = 1.25 \text{ (for steel tension failure acc. to EN 1993-1-1:2014, section 6.1)}$$

$$F_{tens,d} = \frac{24100}{1.25} = 19280 \text{ N}$$

$$F_{ax,Rd} = \min \left\{ \begin{array}{l} F_{ax,Rd} \\ F_{tens,d} \end{array} \right\} = \min \left\{ \begin{array}{l} 14833 \text{ N} \\ 19280 \text{ N} \end{array} \right\} = 14833 \text{ N}$$

determination of the connection resistance

The load-bearing capacity must be reduced by 50 % as only one screw is applied in the connection (see ETA-22/0789:2023, section 2.2)

$$F_{Rd} = \frac{F_{ax,Rd}}{2} = \frac{14833}{2} = 7417 \text{ N}$$

verification

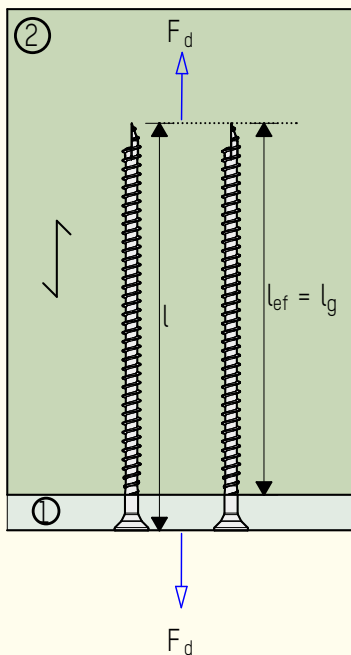
$$F_{Ed} \leq F_{Rd}$$

$$4230 \text{ N} \leq 7417 \text{ N}$$

verification fulfilled (57 %)

SCREWS LOADED IN TENSION

A.2.2 general – axis-grain-angle 0°



DETAILS

service class SC1

loadingpermanent load: $F_{G,k} = 1.80$ kNvariable load: $F_{N,k} = 1.20$ kN

(category A, duration of load medium-term)

construction elements

construction element 1:

steelplate, $t = 10$ mm

construction element 2:

solid timber C24

Wood Screw C-FT-8x240/230 $d = 8$ mm, $l = 240$ mm, $l_g = l_{ef} = 230$ mm

2 screws

minimum spacing

(acc. to ETA- 22/0789:2023, table A6.4)

 $a_2 = 40$ mm $\geq 2.5 \cdot d = 2.5 \cdot 8 = 20$ mm \rightarrow OK $a_{2,c} = 40$ mm $\geq 4 \cdot d = 4 \cdot 8 = 32$ mm \rightarrow OKMinimum penetration length of the screw at an angle of $\leq 15^\circ$ between the screw axis and the grain direction (acc. to ETA-22/0789:2023, section A.2.2) $l - t = 240 - 10 = 230$ mm $\geq 20 \cdot d = 20 \cdot 8 = 160$ mm \rightarrow OKaction design value

$$F_{Ed} = \gamma_G \cdot F_{G,k} + \gamma_Q \cdot F_{N,k} =$$

$$1.35 \cdot 1.80 + 1.5 \cdot 1.20 = 4.23 \text{ kN}$$

determination of the load bearing capacity of the single screw

$$F_{ax,Rd} = \left\{ \begin{array}{l} \text{withdrawal resistance} \\ \text{screw tension resistance} \end{array} \right\}$$

$$F_{ax,Rd} = f_{ax,k,90} \cdot k_{ax} \cdot k_{sys} \cdot \left(\frac{\rho_k}{\rho_{k,ref}} \right)^{k_p} \cdot d \cdot l_{ef} \cdot \frac{k_{mod}}{\gamma_M}$$

$$f_{ax,k,90} = 13.1 \text{ N/mm}^2 \text{ (acc. to ETA- 22/0789:2023, table A6.1)}$$

$$k_{ax} = 0.3 \cdot k_{gap} + \frac{\alpha}{30^\circ} \cdot (1 - 0.3 \cdot k_{gap}) = 0.3 \cdot 1.0 + \frac{0^\circ}{30^\circ} \cdot (1 - 0.3 \cdot 1.0) = 0.3$$

STEEL-TO-TIMBER CONNECTION CALCULATION EXAMPLE



$$k_{\text{gap}} = 1.0$$

$$k_{\text{sys}} = 1.0 \text{ for solid timber}$$

$$\rho_k = 350 \text{ kg/m}^3 \text{ characteristic density of the timber raw material}$$

$$\rho_{k,\text{ref}} = 350 \text{ kg/m}^3 \text{ reference characteristic density of the timber raw material}$$

$$k_p \text{ for softwood and } 0^\circ \leq \alpha \leq 15^\circ:$$

$$k_p = 1.25 \cdot 0.05 d = 1.25 \cdot 0.05 \cdot 8 = 0.85$$

$$l_{\text{ef}} = 230 \text{ mm}$$

$$k_{\text{mod}} = 0.8 \text{ (SC1, duration of load medium-term)}$$

$$\gamma_M = 1.30 \text{ (for connections in timber construction acc. to EN 1995-1-1, table 2.3)}$$

$$F_{\text{ax,Rd}} = 13.1 \cdot 0.3 \cdot 1.00 \cdot \left(\frac{350}{350} \right)^{0.85} \cdot 8 \cdot 230 \cdot \frac{0.8}{1.30} = 4450 \text{ N}$$

design value of the screw tension resistance:

$$F_{\text{tens,d}} = \frac{F_{\text{tens,k}}}{\gamma_{M2}}$$

$$F_{\text{tens,k}} = 24100 \text{ N (acc. to ETA- 22/0789:2023, table A6.1)}$$

$$\gamma_{M2} = 1.25 \text{ (for steel tension failure acc. to EN 1993-1-1:2014, section 6.1)}$$

$$F_{\text{tens,d}} = \frac{24100}{1.25} = 19280 \text{ N}$$

$$F_{\text{ax,Rd}} = \min \left\{ \begin{array}{l} F_{\text{ax,Rd}} \\ F_{\text{tens,d}} \end{array} \right\} = \min \left\{ \begin{array}{l} 4450 \text{ N} \\ 19280 \text{ N} \end{array} \right\} = 4450 \text{ N}$$

determination of the connection resistance

$$F_{\text{Rd}} = n_{\text{ef}} \cdot F_{\text{ax,Rd}}$$

$$n_{\text{ef}} = n^{0.9} = 2^{0.9} = 1.87$$

$$F_{\text{Rd}} = 1.87 \cdot 4450 \text{ N} = 8304 \text{ N}$$

verification

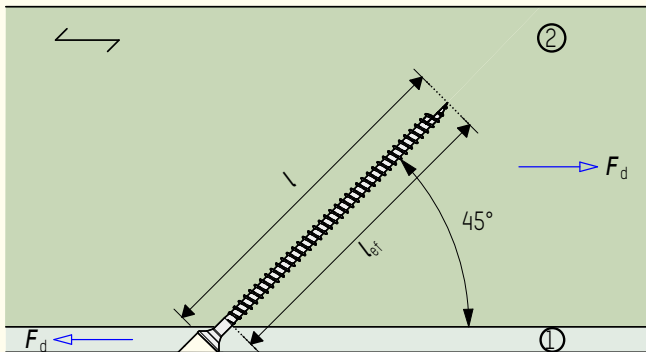
$$F_{\text{Ed}} \leq F_{\text{Rd}}$$

$$4230 \text{ N} \leq 8304 \text{ N}$$

verification fulfilled (51 %)

SCREWS LOADED IN TENSION

A.2.3 general – mainly axially loaded screw



DETAILS

service class SC1

loading

permanent load: $F_{G,k} = 1.80$ kNvariable load: $F_{N,k} = 1.20$ kN

(category A, duration of load medium-term)

construction elements

construction element 1:

steel plate, $t = 10$ mm

construction element 2:

solid timber C24

Wood Screw C-FT-8x240/230

 $d = 8$ mm, $l = 240$ mm, $l_g = l_{ef} = 230$ mm

action design value

$$F_{Ed} = \gamma_G \cdot F_{G,k} + \gamma_Q \cdot F_{N,k} =$$

$$1.35 \cdot 1.80 + 1.5 \cdot 1.20 = 4.23 \text{ kN}$$

determination of the load bearing capacity of the single screw

$$F_{ax,Rd} = \left\{ \begin{array}{l} \text{withdrawal resistance} \\ \text{screw tension resistance} \end{array} \right\}$$

design value of the withdrawal resistance:

$$F_{ax,Rd} = f_{ax,k,90} \cdot k_{ax} \cdot k_{sys} \cdot \left(\frac{\rho_k}{\rho_{k,ref}} \right)^{k_p} \cdot d \cdot l_{ef} \cdot \frac{k_{mod}}{\gamma_M}$$

 $f_{ax,k,90}$ 13.1 N/mm² (acc. to ETA-22/0789:2023, table A6.1) k_{ax} 1.0 for $30^\circ \leq \alpha \leq 90^\circ$ k_{sys} 1.0 for solid timber ρ_k 350 kg/m³ characteristic density of the timber raw material $\rho_{k,ref}$ 350 kg/m³ reference characteristic density of the timber raw material k_p 1.10 for softwood and $15^\circ \leq \alpha \leq 90^\circ$ l_{ef} 230 mm k_{mod} 0.8 (SC1, duration of load medium-term) γ_M 1.30 (for connections in timber construction acc. to EN 1995-1-1, table 2.3)

$$F_{ax,Rd} = 13.1 \cdot 1.0 \cdot 1.10 \cdot \left(\frac{350}{350} \right)^{1.10} \cdot 8 \cdot 230 \cdot \frac{0.8}{1.30} = 14833 \text{ N}$$

STEEL-TO-TIMBER CONNECTION CALCULATION EXAMPLE



design value of the screw tension resistance:

$$F_{\text{tens,d}} = \frac{F_{\text{tens,k}}}{\gamma_{M2}}$$

$$F_{\text{tens,k}} \quad 24100 \text{ N (acc. to ETA-22/0789:2023, table A6.1)}$$

$$\gamma_{M2} \quad 1.25 \text{ (for steel tension failure acc. to EN 1993-1-1:2014, section 6.1)}$$

$$F_{\text{tens,d}} = \frac{24100}{1.25} = 19280 \text{ N}$$

$$F_{\text{ax,Rd}} = \min \left\{ \begin{array}{l} F_{\text{ax,Rd}} \\ F_{\text{tens,d}} \end{array} \right\} = \min \left\{ \begin{array}{l} 14833 \text{ N} \\ 19280 \text{ N} \end{array} \right\} = 14833 \text{ N}$$

determination of the connection resistance

The load-bearing capacity must be reduced by 50 % as only one screw is applied in the connection (see ETA-22/0789:2023, section 2.2)

$$F_{\text{Rd}} = \frac{F_{\text{ax,Rd}} \cdot (\cos(\alpha) + \mu \cdot \sin(\alpha))}{2}$$

μ 0.3 friction coefficient between the elements timber and steel (acc. to ETA- 22/0789:2023, section A.7.1)

$$F_{\text{Rd}} = \frac{14833 \cdot (\cos(45) + \mu \cdot \sin(45))}{2} = \frac{13635}{2} = 6818 \text{ N}$$

verification

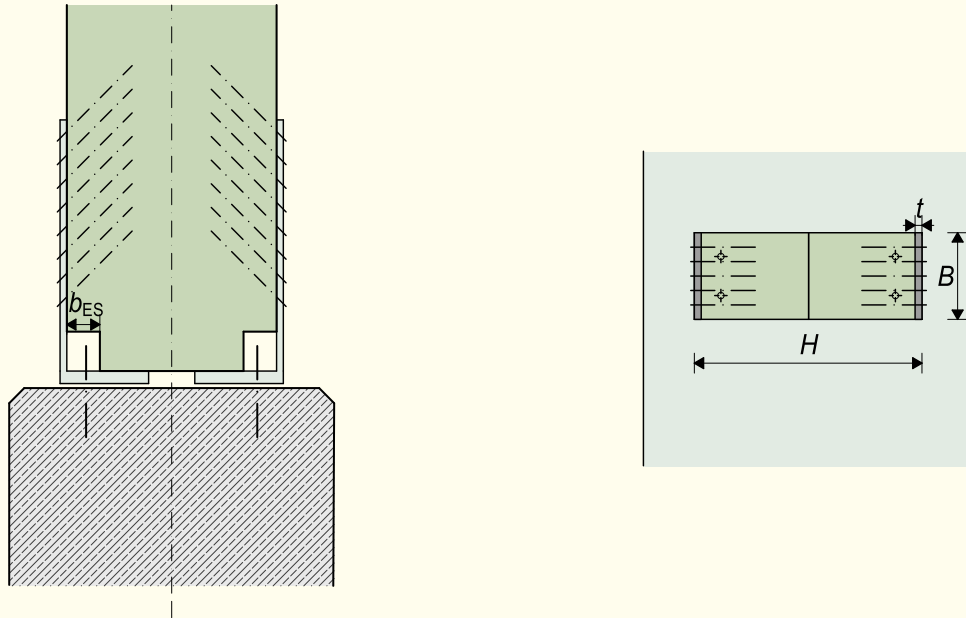
$$F_{\text{Ed}} \leq F_{\text{Rd}}$$

$$4230 \text{ N} \leq 6818 \text{ N}$$

verification fulfilled (62 %)

SCREWS LOADED IN TENSION

A.2.4 column support, steel plate with inclined screws

**DETAILS**

service class SC1

loading

maximum moment at support $M_{Ed} = 456 \text{ kNm}$

accompanying normal force $N_{Ed} = -217 \text{ kN}$

(duration of load short-term)

timber column

glue laminated timber GL24h

$B = 260 \text{ mm}$, $H = 880 \text{ mm}$

$b_{ES} = 100 \text{ mm}$, $t = 20 \text{ mm}$

Wood Screw C-FT-10x350/326

$d = 10 \text{ mm}$, $l = 350 \text{ mm}$, $l_{ef} = 326 \text{ mm}$



determination load bearing capacity of gross section

$$\left(\frac{\sigma_{c,0,d}}{f_{c,0,d}} \right)^2 + \frac{\sigma_{m,y,d}}{f_{m,y,d}} \leq 1$$

$f_{m,y,k}$ 24 N/mm², characteristic bending strength

k_{mod} 0.9 (SC1, duration of load short-term)

γ_M 1.25 (for glue laminated timber acc. to EN 1995-1-1, table 2.3)

$$f_{m,y,d} = f_{m,y,k} \cdot \frac{k_{mod}}{\gamma_M} = 24 \cdot \frac{0.9}{1.25} = 17.3 \text{ N/mm}^2$$

$f_{c,0,d}$ 24 N/mm², characteristic compressive strength parallel to grain

$$f_{c,0,d} = f_{c,0,k} \cdot \frac{k_{mod}}{\gamma_M} = 24 \cdot \frac{0.9}{1.25} = 17.3 \text{ N/mm}^2$$

A_{gross} gross cross section

$$A_{gross} = B \cdot H = 260 \cdot 880 = 228800 \text{ mm}^2$$

$$W_{gross} = \frac{B \cdot H^2}{6} = \frac{260 \cdot 880^2}{6} = 3.36 \cdot 10^7 \text{ mm}^3$$

$\sigma_{m,y,d}$ design value of the bending stress

$$\sigma_{m,y,d} = \frac{M_{Ed}}{W_{gross}} = \frac{456 \cdot 10^6}{3.36 \cdot 10^7} = 13.6 \text{ N/mm}^2$$

$\sigma_{c,0,d}$ design value of the compressive stress

$$\sigma_{c,0,d} = \frac{N_{Ed}}{A_{gross}} = \frac{217 \cdot 10^3}{228800} = 0.9 \text{ N/mm}^2$$

$$\left(\frac{0.9}{17.3} \right)^2 + \frac{13.6}{17.3} \leq 1$$

$$0.00 + 0.79 \leq 1$$

verification fulfilled (79%)

determination of the load bearing capacity of the single screw

$$F_{ax,Rd} = \min \left\{ \begin{array}{l} \text{withdrawal resistance} \\ \text{screw tension resistance} \end{array} \right\}$$

design value of the withdrawal resistance:

$$F_{ax,45,Rd} = f_{ax,k,90} \cdot k_{ax} \cdot k_{sys} \cdot \left(\frac{\rho_k}{\rho_{k,ref}} \right)^{k_p} \cdot d \cdot l_{ef} \cdot \frac{k_{mod}}{\gamma_M}$$

SCREWS LOADED IN TENSION

A.2.4 column support, steel plate with inclined screws

$f_{ax,k,90}$	12.5 N/mm ² (acc. to ETA-22/0789:2023, table A6.1)
k_{ax}	1.0 for $30^\circ \leq \alpha \leq 90^\circ$
k_{sys}	1.15 for 6 penetrated layers (acc. to ETA-22/0789:2023, table A6.6)
ρ_k	350 kg/m ³ characteristic density of the timber raw material
$\rho_{k,ref}$	350 kg/m ³ reference characteristic density of the timber raw material
k_p	1.10 for softwood and $15^\circ \leq \alpha \leq 90^\circ$
l_{ef}	326 mm
k_{mod}	0.9 (SC1, duration of load short-term)
γ_M	1.30 (for connections in timber construction acc. to EN 1995-1-1, table 2.3)

$$F_{ax,45,Rd} = 12.5 \cdot 1.0 \cdot 1.15 \cdot \left(\frac{385}{350}\right)^{1.10} \cdot 10 \cdot 326 \cdot \frac{0.9}{1.30} = 36029 \text{ N}$$

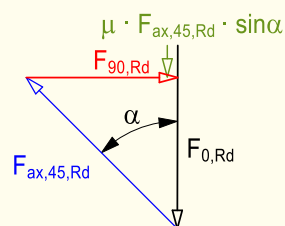
design value of the screw tension resistance:

$$F_{tens,d} = \frac{F_{tens,k}}{\gamma_{M2}} = \frac{40000}{1.25} = 32000 \text{ N}$$

$F_{tens,k}$	40000 N (acc. to ETA- 22/0789:2023, table A6.1)
γ_{M2}	1.25 (for steel tension failure acc. to EN 1993-1-1:2014, section 6.1)

$$F_{ax,45,Rd} = \min \left\{ \begin{array}{l} F_{ax,45,Rd} \\ F_{tens,d} \end{array} \right\} = \min \left\{ \begin{array}{l} 36029 \text{ N} \\ 32000 \text{ N} \end{array} \right\} = 32000 \text{ N}$$

determination of the vertical force component of the design value of the single screw (mainly axially loaded), see equilibrium of forces of the screw:



$$F_{0,Rd} = F_{ax,45,Rd} \cdot (\cos \alpha + \mu \cdot \sin \alpha)$$

μ 0.3 friction coefficient between the elements timber and steel (acc. to ETA- 22/0789:2023, section A7.1)

$$F_{0,Rd} = 32000 \cdot (\cos 45 + 0.3 \cdot \sin 45) = 29416 \text{ N}$$

STEEL-TO-TIMBER CONNECTION CALCULATION EXAMPLE



determination of required number of screws and the screw assembly

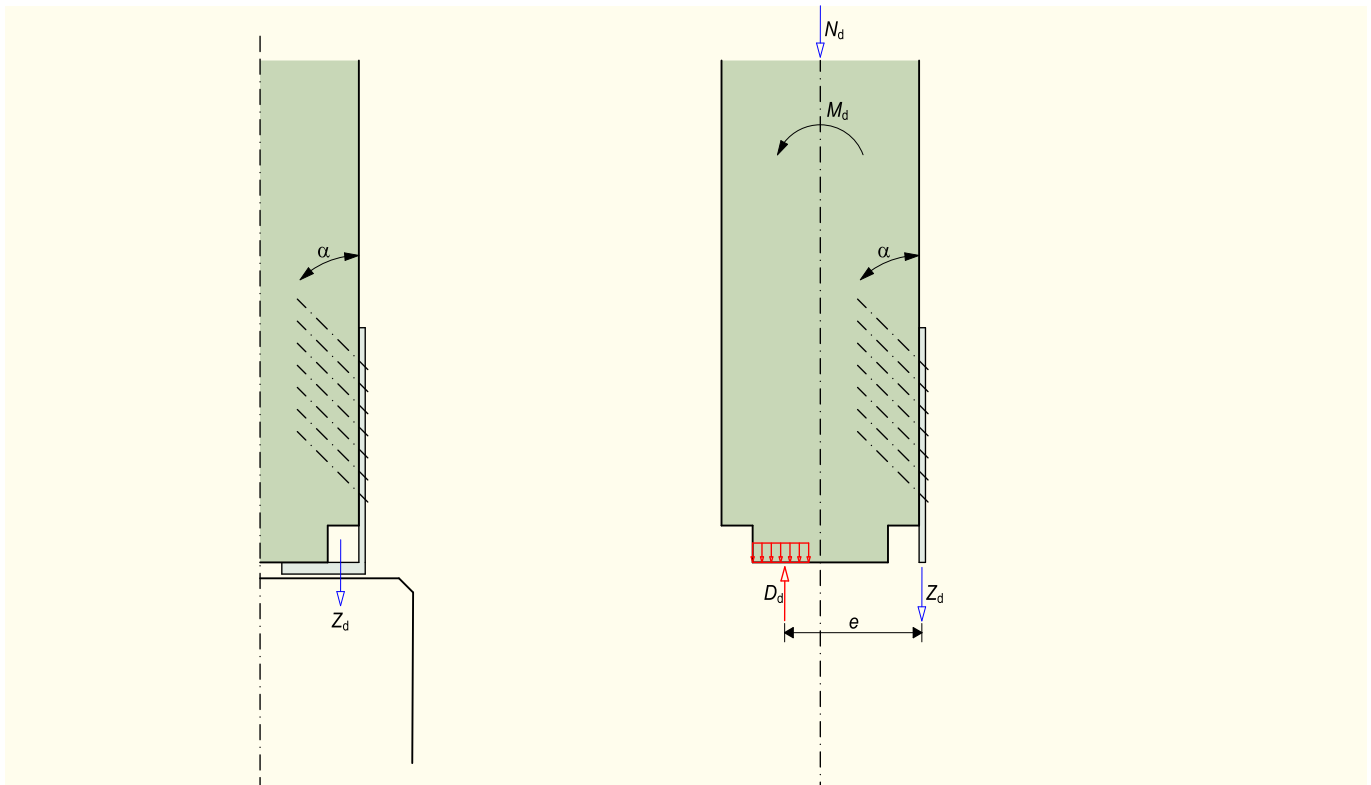
The screw connection must fulfill the following conditions:

$$F_{0,Ed} \leq n_{ef} \cdot F_{0,Rd}$$

$F_{0,Ed}$ corresponds to the tensile force Z_d . The normal force N_{Ed} leads to a compressive force in the cross section and possibly to a reduction of the tensile force in the steel outer plate. Conservatively, this compressive force is not taken into account for the verification of the tensile load of the screws.

$$F_{0,Ed} = \frac{M_{Ed}}{e}$$

The length $l_{c,0}$ of the area subjected to the compressive force D_d is assumed to be $0.25 \cdot H$. This results in the assumption of the length e for the lever arm.



simplified assumption

$$e = H - b_{ES} - \frac{H}{4} = 880 - 100 - \frac{880}{4} = 560 \text{ mm}$$

$$F_{0,Ed} = \frac{456 \cdot 10^6}{560} = 814000 \text{ N}$$

$$n_{ef} \geq \frac{F_{0,Ed}}{F_{0,Rd}} = \frac{814000}{29416} = 27.7$$

SCREWS LOADED IN TENSION

A.2.4 column support, steel plate with inclined screws

In accordance with the minimum spacing $a_{2,c}$ and a_2 , as well as a_1 (acc. to ETA-22/0789:2023, table A6.4), the number of screws perpendicular (n_{90}) and parallel (n_0) to the grain direction is selected as follows:

$$n_{90} = 5 \text{ screws}$$

$$n_0 = 7 \text{ screws}$$

$$n = n_{90} \cdot n_0 = 5 \cdot 7 = 35 \text{ screws}$$

this results in the following spacing:

$$a_{2,c} = 4 \cdot d = 4 \cdot 10 = 40 \text{ mm}$$

$$a_2 = (B - 2 \cdot a_{2,c}) / (n_{90} - 1) = (260 - 2 \cdot 40) / (5 - 1) = 45 \text{ mm}$$

$$a_1 \cdot a_2 \geq 25 \cdot d^2 = 25 \cdot 10^2 = 2500 \rightarrow a_1 \geq 56 \text{ mm (selected 60 mm)}$$

$$n_{ef} \quad (\text{acc. to ETA-22/0789:2023, section A.6.1.1})$$

$$n_{ef} = \max \left\{ \begin{array}{l} n^{0.9} \\ 0.9 \cdot n \end{array} \right\} = \max \left\{ \begin{array}{l} 24.5 \\ 31.5 \end{array} \right\} = 31.5$$

$$F_{0,Ed} \leq n_{ef} \cdot F_{0,Rd}$$

$$814000 \text{ N} \leq 31.5 \cdot 29416 = 926593 \text{ N}$$

verification fulfilled (88 %)

verification of compression parallel-to-grain close to end grain

$$\sigma_{c,0,Ed} \leq f_{c,0,d}$$

$$f_{c,0,d} = f_{c,0,k} \cdot \frac{k_{mod}}{\gamma_M} = 24 \cdot \frac{0.9}{1.25} = 17.3 \text{ N/mm}^2$$

$$f_{c,0,d} \quad 24 \text{ N/mm}^2, \text{ characteristic compressive strength parallel to grain}$$

$$k_{mod} \quad 0.9 \text{ (SC1, duration of load short-term)}$$

$$\gamma_M \quad 1.25 \text{ (for glue laminated timber acc. to EN 1995-1-1, table 2.3)}$$

$$\sigma_{c,0,Ed} = \frac{D_d + D_{N,d}}{(B \cdot l_{c,0})}$$

The design load part $D_{N,d}$ of the acting normal force N_{Ed} is assumed according to the proportion of the assumed area subjected by compression, load A_M , of the total cross sectional area A_{net} :

$$A_{net} = (H - 2 \cdot B_{ES}) \cdot B = (880 - 2 \cdot 100) \cdot 260 = 176800 \text{ mm}^2$$

$$A_M = \frac{H}{4} \cdot B = \frac{880}{4} \cdot 260 = 57200 \text{ mm}^2$$

$$D_{N,d} = N_{Ed} \cdot \frac{A_M}{A_{net}} = 217 \cdot 10^3 \cdot \frac{57200}{176800} = 70206 \text{ N}$$

STEEL-TO-TIMBER CONNECTION CALCULATION EXAMPLE



verification:

$$\sigma_{c,0,Ed} = \frac{814000 + 70206}{(260 \cdot 560)} = 6.1 \text{ N/mm}^2 \leq 17.3 \text{ N/mm}^2$$

verification fulfilled (35 %)

determination of block shear failure

The verification of block shear failure of connections is made acc. to EN 1995-1-1 annex A.

$$F_{bs,Rd} = \max \left\{ \begin{array}{l} 1.5 \cdot A_{net,t} \cdot f_{t,0,d} \\ 0.7 \cdot A_{net,v} \cdot f_{v,d} \end{array} \right\}$$

$$L_{net,t} = l \cdot \sin \alpha - t = 350 \cdot \sin 45 - 10 = 237 \text{ mm}$$

$$A_{net,t} = L_{net,t} \cdot B = 237 \cdot 260 = 61747 \text{ mm}^2$$

$$L_{net,v} = (n_0 - 1) \cdot a_1 + (l \cdot \cos \alpha - 10) + a = (7 - 1) \cdot 60 + (350 \cdot \cos 45 - 10) + 60 = 667 \text{ mm}$$

$$A_{net,v} = L_{net,v} \cdot B = 667 \cdot 260 = 173547 \text{ mm}^2$$

$$f_{t,0,d} = f_{t,0,k} \cdot \frac{k_{mod}}{\gamma_M} = 19.2 \cdot \frac{0.9}{1.30} = 13.3 \text{ N/mm}^2$$

$$k_{mod} \quad 0.9 \text{ (SC1, duration of load short-term)}$$

$$\gamma_M \quad 1.30 \text{ (for connections in timber construction acc. to EN 1995-1-1, table 2.3)}$$

$$f_{v,d} = f_{v,k} \cdot \frac{k_{mod}}{\gamma_M} = 2.5 \cdot \frac{0.9}{1.30} = 1.73 \text{ N/mm}^2$$

$$F_{bs,Rd} = \max \left\{ \begin{array}{l} 1.5 \cdot 61747 \cdot 13.3 \\ 0.7 \cdot 173547 \cdot 1.73 \end{array} \right\} = \max \left\{ \begin{array}{l} 1231853 \\ 210259 \end{array} \right\} = 1231853 \text{ N}$$

verification

$$F_{0,Ed} \leq F_{bs,Rd}$$

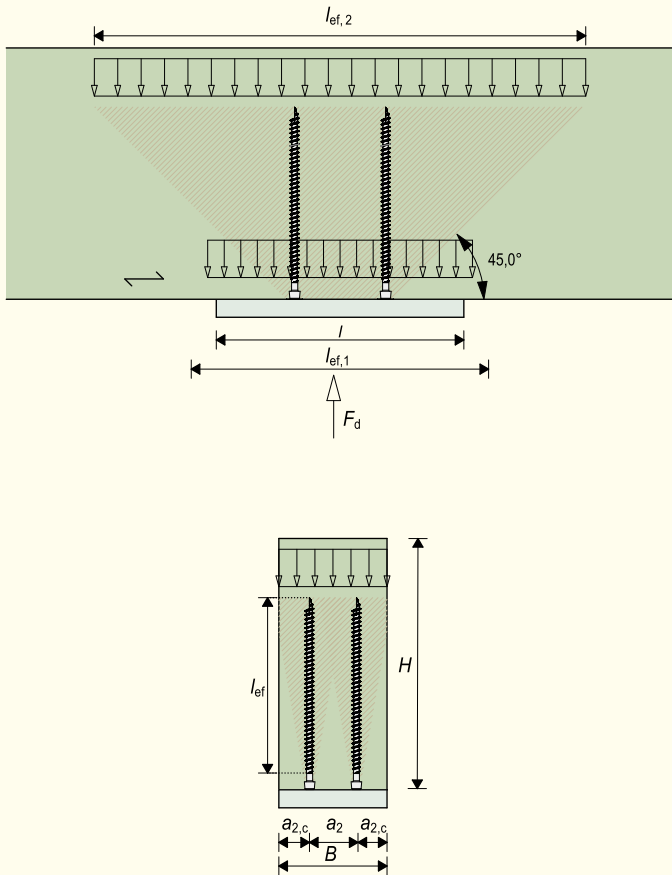
$$814000 \text{ N} \leq 1231853 \text{ N}$$

verification fulfilled (66 %)

Additionally, the load-bearing capacity of the steel plates and the connection to the foundation must be verified in accordance to the relevant standards.

REINFORCEMENT

A.3.1 support - reinforcement for compression perpendicular to grain



DETAILS

service class SC1

loading

 permanent load: $F_{G,k} = 25.0$ kN

 variable load: $F_{N,k} = 47.5$ kN

(category A, duration of load medium-term)

construction element

glue laminated timber GL24h

timber cross section and support area

 $B = 140$ mm, $H = 340$ mm,

 support length $l = 140$ mm

Wood Screw CY-FT-8x220/210

 $d = 8$ mm, $l_g = l_{ef} = 210$ mm, $d_i = 5.1$ mm

4 screws

minimum spacing

(acc. to ETA-22/0789:2023, table A6.4)

 $a_1 = 80$ mm $\geq 5 \cdot d = 5 \cdot 8 = 40$ mm \rightarrow ok

 $a_2 = 70$ mm $\geq 2.5 \cdot d = 2.5 \cdot 8 = 20$ mm \rightarrow ok

 $a_{2,c} = 35$ mm $\geq 4 \cdot d = 4 \cdot 8 = 32$ mm \rightarrow ok

action design value

$$F_{Ed} = \gamma_G \cdot F_{G,k} + \gamma_Q \cdot F_{N,k} =$$

$$1.35 \cdot 25.0 + 1.5 \cdot 47.5 = 105.0 \text{ kN} \hat{=} 105000 \text{ N}$$

determination of load bearing capacity of compression perpendicular to grain without reinforcement

$$F_{c,90,Rd} = k_{c,90} \cdot B_1 \cdot l_{ef} \cdot f_{c,90,k} \cdot \frac{k_{mod}}{\gamma_M}$$

 $k_{c,90}$ 1.75 for glue laminated timber acc. to EN 1995-1-1, section 6.1.5(4)

 B_1 140 mm (minimum of the width of the timber and the width of the support)

 l_{ef} effective contact length of the support acc. to EN 1995-1-1, section 6.1.5(1)

$$l_{ef} = l + 2 \cdot 30 = 140 + 2 \cdot 30 = 200 \text{ mm}$$

 $f_{c,90,k}$ 2.5 N/mm² for glue laminated timber lt. EN 14080:2013

 k_{mod} 0.8 (SC1, duration of load medium-term)

 γ_M 1.25 (for glue laminated timber acc. to EN 1995-1-1, table 2.3)

CALCULATION EXAMPLE



$$F_{c,90,Rd} = 1.75 \cdot 140 \cdot 200 \cdot 2.5 \cdot \frac{0.8}{1.30} = 78400 \text{ N}$$

verification without reinforcement:

$$F_{Ed} \leq F_{c,90,Rd} = 1.75 \cdot 140 \cdot 200 \cdot 2.5 \cdot \frac{0.8}{1.30} = 78400 \text{ N}$$

$$105000 \text{ N} > 78400 \text{ N}$$

verification not fulfilled (134 %)

A reinforcement is required.

load bearing capacity of compression perpendicular to grain with reinforcement

$$F_{c,90,Rd} = \min \left\{ \begin{array}{l} k_{c,90} \cdot B_1 \cdot l_{ef,1} \cdot f_{c,90,k} \cdot \frac{k_{mod}}{\gamma_M} + n \cdot \min \left(\frac{F_{ax,Rd}}{\gamma_{M1}}, \frac{N_{pl,k}}{\gamma_{M1}} \right) \\ B_2 \cdot l_{ef,2} \cdot f_{c,90,k} \cdot \frac{k_{mod}}{\gamma_M} \end{array} \right\}$$

design value of the withdrawal resistance (pushing in):

$$F_{ax,Rd} = f_{ax,k,90} \cdot k_{ax} \cdot k_{sys} \cdot \left(\frac{\rho_k}{\rho_{k,ref}} \right)^{k_p} \cdot d \cdot l_{ef} \cdot \frac{k_{mod}}{\gamma_M}$$

$$f_{ax,k,90} \quad 13.1 \text{ N/mm}^2 \text{ (acc. to ETA- 22/0789:2023, table A6.1)}$$

$$k_{ax} \quad 1.0 \text{ for } 30^\circ \leq \alpha \leq 90^\circ$$

$$k_{sys} \quad 1.15 \text{ for 6 penetrated layers (acc. to ETA- 22/0789:2023, table A6.6)}$$

$$\rho_k \quad 350 \text{ kg/m}^3 \text{ characteristic density of the timber raw material}$$

$$\rho_{k,ref} \quad 350 \text{ kg/m}^3 \text{ reference characteristic density of the timber raw material}$$

$$k_p \quad 1.10 \text{ for softwood and } 15^\circ \leq \alpha \leq 90^\circ$$

$$l_{ef} \quad 210 \text{ mm}$$

$$k_{mod} \quad 0.8 \text{ (SC1, duration of load medium-term)}$$

$$\gamma_M \quad 1.30 \text{ (for connections in timber construction acc. to EN 1995-1-1, table 2.3)}$$

$$F_{ax,Rd} = 13.1 \cdot 1.0 \cdot 1.15 \cdot \left(\frac{385}{350} \right)^{1.10} \cdot 8 \cdot 210 \cdot \frac{0.8}{1.30} = 17296 \text{ N}$$

REINFORCEMENT

A.3.1 support - reinforcement for compression perpendicular to grain

design value of the buckling resistance:

$$F_{ki,Rd} = \kappa_c \cdot \frac{N_{pl,k}}{\gamma_{M1}}$$

$$\kappa_c = \begin{cases} 1.0 & \text{für } \bar{\lambda}_k \leq 0.2 \\ \frac{1.0}{k + \sqrt{k^2 - \bar{\lambda}_k^2}} & \text{für } \bar{\lambda}_k > 0.2 \end{cases} = \frac{1.0}{1.006 + \sqrt{1.006^2 - 0.837^2}} = 0.63$$

$$k = 0.5 \cdot \left[1 + 0.49 \cdot (\bar{\lambda}_k - 0.2) + \bar{\lambda}_k^2 \right] = 0.5 \cdot \left[1 + 0.49 \cdot (0.837 - 0.2) + 0.837^2 \right] = 1.006$$

$$\bar{\lambda}_k = \sqrt{\frac{N_{pl,k}}{N_{ki,k}}} = \sqrt{\frac{19407}{27711}} = 0.837$$

$$N_{pl,k} = \pi \cdot \frac{d_f^2}{4} \cdot f_{y,k} = \pi \cdot \frac{5.1^2}{4} \cdot 950 = 19407 \text{ N}$$

$$f_{y,k} \quad 950 \text{ N/mm}^2 \text{ acc. ETA-22/0789:2023, table A6.1}$$

$$N_{ki,k} = \sqrt{c_h \cdot E_s \cdot I_s} = \sqrt{110.1 \cdot 210000 \cdot 33.2} = 27711 \text{ N}$$

$$c_h = (0.19 + 0.012 \cdot d) \cdot \rho_k \cdot \left(\frac{90 + \alpha}{180} \right) = (0.19 + 0.012 \cdot 8) \cdot 385 \cdot \left(\frac{90 + 90}{180} \right) = 110.1 \text{ N/mm}^2$$

$$E_s \quad 210000 \text{ N/mm}^2 \text{ acc. ETA-22/0789:2023, table A6.1)}$$

$$I_s = \frac{\pi \cdot d_f^4}{64} = \frac{\pi \cdot 5.1^4}{64} = 33.2 \text{ mm}^2$$

$$\gamma_{M1} \quad 1.00 \text{ (for stability failure of steel elements acc. EN 1993-1-1:2014, section 6.1)}$$

$$F_{ki,Rd} = 0.63 \cdot \frac{19407}{1.00} = 12402 \text{ N}$$

determination of load bearing capacity of compression perpendicular to grain at the depth of the screw tips:

$$F_{c,90,Rd,2} = B_2 \cdot l_{ef,2} \cdot f_{c,90,k} \cdot \frac{k_{mod}}{\gamma_M}$$

$l_{ef,2}$ effective length at the depth of screw tips - for an intermediate support acc. to ETA-22/0789:2023, section A.8.1

$$l_{ef,2} = 2 \cdot l_{ef} + (n_0 - 1) \cdot a_1 = 2 \cdot 210 + (2 - 1) \cdot 80 = 500 \text{ mm}$$

$$F_{c,90,Rd,2} = 140 \cdot 500 \cdot 2.5 \cdot \frac{0.8}{1.25} = 112000 \text{ N}$$

CALCULATION EXAMPLE



determination of the connection resistance

n number of reinforcement screws perpendicular and parallel to grain

$$n = n_0 \cdot n_{90} = 2 \cdot 2 = 4$$

$$F_{c,90,Rd} = \min \left\{ \begin{array}{l} 78400 + 4 \cdot \min \left(\begin{array}{l} 17296 \\ 12402 \end{array} \right) \\ 112000 \end{array} \right\} = 112000 \text{ N}$$

verification

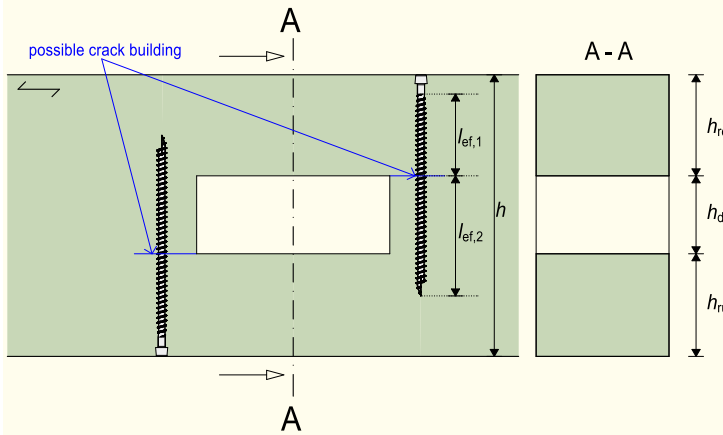
$$F_{Ed} \leq F_{c,90,Rd}$$

$$105000 \text{ N} \leq 112000 \text{ N}$$

verification fulfilled (94 %)

REINFORCEMENT

A.3.2 reinforcement of openings



DETAILS

service class SC1

loading

 bending moment: $M_d = 16 \text{ kNm}$

 lateral force: $V_d = 20 \text{ kN}$

(duration of load medium-term)

construction element

glue laminated timber GL24h

 $h = 240 \text{ mm}$, $h_d = 70 \text{ mm}$
 $h_{ru} = h_{ro} = 85 \text{ mm}$

Wood Screw CY-FT-8x200/190

 $d = 8 \text{ mm}$, $l = 200 \text{ mm}$, $l_g = 190 \text{ mm}$
 $l_{ef,1} = 75 \text{ mm}$, $l_{ef,2} = 125 \text{ mm}$

2 screws each side of the opening

load bearing capacity of the reinforcement of the opening

The reinforcement of the opening is verified acc. to ETA- 22/0789:2023, section A.8.2.2)

$$F_{t,V,d} + F_{t,M,d} \leq F_{ax,Rd}$$

 $F_{t,V,d}$ tension perpendicular to grain as a result of the lateral force V_d

$$F_{t,V,d} = \frac{V_d \cdot h_d}{4 \cdot h} \cdot \left(3 - \frac{h_d^2}{h^2} \right) = \frac{20000 \cdot 70}{4 \cdot 240} \cdot \left(3 - \frac{70^2}{240^2} \right) = 4375 \text{ N}$$

 $F_{t,M,d}$ tension perpendicular to grain as a result of the bending moment M_d

$$F_{t,M,d} = 0.008 \cdot \frac{M_d}{h_r} = 0.008 \cdot \frac{16000000}{75} = 1506 \text{ N}$$

determination of the load bearing capacity of the screws:

$$F_{ax,Rd} = n_{90} \cdot \min \left\{ \begin{array}{l} F_{ax,90,Rd} \\ F_{tens,d} \end{array} \right\}$$

design value of the withdrawal resistance:

$$F_{ax,90,Rd} = f_{ax,k,90} \cdot k_{ax} \cdot k_{sys} \cdot \left(\frac{\rho_k}{\rho_{k,ref}} \right)^{k_p} \cdot d \cdot l_{ef} \cdot \frac{k_{mod}}{\gamma_M}$$

 $f_{ax,k,90}$ 13.1 N/mm² (acc. to ETA- 22/0789:2023, table A6.1)

 k_{ax} 1.0 for $30^\circ \leq \alpha \leq 90^\circ$

CALCULATION EXAMPLE



- k_{sys} 1.06 for 2 penetrated layers (acc. to ETA-22/0789:2023, table A6.6)
 ρ_k 350 kg/m³ characteristic density of the timber raw material
 $\rho_{k,\text{ref}}$ 350 kg/m³ reference characteristic density of the timber raw material
 k_p 1.10 for softwood and $15^\circ \leq \alpha \leq 90^\circ$
 l_{ef} $\min\{l_{\text{ef},1}; l_{\text{ef},2}\} = 75$ mm
 k_{mod} 0.8 (SC1, duration of load medium-term)
 γ_M 1.30 (for connections in timber construction acc. to EN 1995-1-1, table 2.3)

$$F_{\text{ax},90,\text{Rd}} = 13.1 \cdot 1.0 \cdot 1.06 \cdot \left(\frac{385}{350}\right)^{1.10} \cdot 8 \cdot 75 \cdot \frac{0.8}{1.30} = 5694 \text{ N}$$

design value of the screw tension resistance:

$$F_{\text{tens},d} = \frac{F_{\text{tens},k}}{\gamma_{M2}} = \frac{24100}{1.25} = 19280 \text{ N}$$

$F_{\text{tens},k}$ 24100 N (acc. to ETA-22/0789:2023, table A6.1)

γ_{M2} 1.25 (for steel tension failure acc. to EN 1993-1-1:2014, section 6.1)

determination of the resistance of the screws

$$n_{90} = 2$$

$$F_{\text{ax},\text{Rd}} = 2 \cdot \min\left\{\begin{matrix} 5694 \\ 19280 \end{matrix}\right\} = 2 \cdot 5694 = 11388 \text{ N}$$

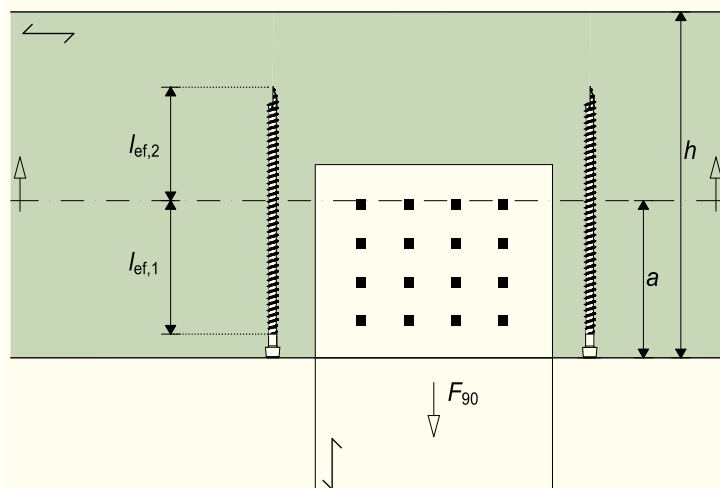
verification

$$4375 + 1506 = 5881 \text{ N} \leq 11388 \text{ N}$$

verification fulfilled (52 %)

REINFORCEMENT

A.3.3 reinforcement of a connection loading the timber perpendicular to grain



DETAILS

service class SC1

loading

$$F_{90,Ed} = 10 \text{ kN}$$

(duration of load medium-term)

construction element

glue laminated timber GL24h

$$h = 240 \text{ mm}, a = 120 \text{ mm}$$

Wood Screw CY-FT-8x200/190

$$d = 8 \text{ mm}, l = 200 \text{ mm},$$

$$l_{ef,1} = 110 \text{ mm}, l_{ef,2} = 80 \text{ mm}$$

2 screws each side of the transverse connection

load bearing capacity of the reinforcement of the connection loading the timber perpendicular to grain

The reinforcement of the opening is verified acc. to ETA- 22/0789:2023, section A8.2.1

$$F_{90,Ed} \cdot \left[1 - 3 \cdot \left(\frac{a}{h} \right)^2 + \left(\frac{a}{h} \right)^3 \right] \leq F_{ax,Rd}$$

determination of the load bearing capacity of the screws:

$$F_{ax,Rd} = n_{90} \cdot \min \left\{ \begin{array}{l} F_{ax,90,Rd} \\ F_{tens,d} \end{array} \right\}$$

design value of the withdrawal resistance:

$$F_{ax,90,Rd} = f_{ax,k,90} \cdot k_{ax} \cdot k_{sys} \cdot \left(\frac{\rho_k}{\rho_{k,ref}} \right)^{k_p} \cdot d \cdot l_{ef} \cdot \frac{k_{mod}}{\gamma_M}$$

$f_{ax,k,90}$ 13.1 N/mm² (acc. to ETA-22/0789:2023, table A6.1)

k_{ax} 1.0 for $30^\circ \leq \alpha \leq 90^\circ$

k_{sys} 1.06 for 2 penetrated layers (acc. to ETA-22/0789:2023, table A6.6)

ρ_k 385 kg/m³ characteristic density of the timber raw material

$\rho_{k,ref}$ 350 kg/m³ reference characteristic density of the timber raw material

k_p 1.10 for softwood and $15^\circ \leq \alpha \leq 90^\circ$

l_{ef} $\min\{l_{ef,1}; l_{ef,2}\} = 80 \text{ mm}$

k_{mod} 0.8 (SC1, duration of load medium-term)

γ_M 1.30 (for connections in timber construction acc. to EN 1995-1-1, table 2.3)

CALCULATION EXAMPLE



$$F_{ax,90,Rd} = 13.1 \cdot 1.0 \cdot 1.06 \cdot \left(\frac{385}{350}\right)^{1.10} \cdot 8 \cdot 80 \cdot \frac{0.8}{1.30} = 6073 \text{ N}$$

design value of the screw tension resistance:

$$F_{tens,d} = \frac{F_{tens,k}}{\gamma_{M2}}$$

$$F_{tens,d} = \frac{24100}{1.25} = 19280 \text{ N}$$

$F_{tens,k}$ 24100 N (acc. to ETA-22/0789:2023, table A6.1)

γ_{M2} 1.25 (for steel tension failure acc. to EN 1993-1-1:2014, section 6.1)

determination of the resistance of the screws

$$n_{90} = 2$$

$$F_{ax,Rd} = 2 \cdot \min \left\{ \begin{array}{l} 6073 \\ 19280 \end{array} \right\} = 2 \cdot 6073 = 12146 \text{ N}$$

verification

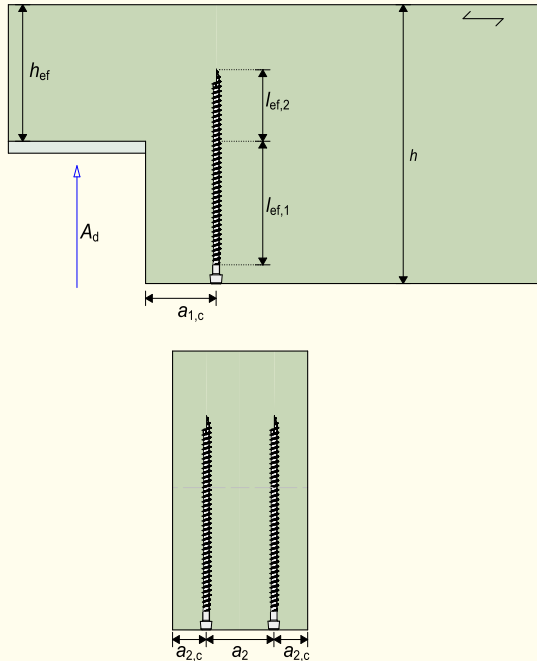
$$10000 \cdot \left[1 - 3 \cdot \left(\frac{120}{240}\right)^2 + \left(\frac{120}{240}\right)^3 \right] \leq 12146$$

$$5000 \text{ N} \leq 12146 \text{ N}$$

verification fulfilled (41 %)

REINFORCEMENT

A.3.4 reinforcement of a notch



DETAILS

service class SC1

loadingsupport load $A_d = V_d = 10$ kN
(duration of load medium-term)construction elementglue laminated timber GL24h
 $h = 240$ mm, $h_{ef} = 120$ mm, $b = 120$ mmWood Screw CY-FT-8x180/170 $d = 8$ mm, $l = 180$ mm, $l_g = 170$ mm, $l_{ef,1} = 110$ mm, $l_{ef,2} = 60$ mm

2 screws

minimum spacing

(acc. to ETA- 22/0789:2023, table A6.4)

$$a_{1,c} = 50 \text{ mm} \geq 5 \cdot d = 5 \cdot 8 = 40 \text{ mm} \rightarrow \text{ok}$$

$$a_2 = 50 \text{ mm} \geq 2.5 \cdot d = 2.5 \cdot 8 = 20 \text{ mm} \rightarrow \text{ok}$$

$$a_{2,c} = 35 \text{ mm} \geq 4 \cdot d = 4 \cdot 8 = 32 \text{ mm} \rightarrow \text{ok}$$

load bearing capacity of the reinforcement of the notch

The reinforcement of the notch is verified acc. to ETA- 22/0789:2023, section A.8.2.1

$$1.3 \cdot V_d \cdot \left[3 \cdot \left(1 - \frac{h_{ef}}{h} \right)^2 - 2 \cdot \left(1 - \frac{h_{ef}}{h} \right)^3 \right] \leq F_{ax,Rd}$$

determination of the load bearing capacity of the screws:

$$F_{ax,Rd} = n_{90} \cdot \min \left\{ \begin{array}{l} F_{ax,90,Rd} \\ F_{tens,d} \end{array} \right\}$$

design value of the withdrawal resistance:

$$F_{ax,90,Rd} = f_{ax,k,90} \cdot k_{ax} \cdot k_{sys} \cdot \left(\frac{\rho_k}{\rho_{k,ref}} \right)^{k_p} \cdot d \cdot l_{ef} \cdot \frac{k_{mod}}{\gamma_M}$$

 $f_{ax,k,90}$ 13.1 N/mm² (acc. to ETA- 22/0789:2023, table A6.1) k_{ax} 1.0 for $30^\circ \leq \alpha \leq 90^\circ$ k_{sys} 1.06 for 2 penetrated layers (acc. to ETA- 22/0789:2023, table A6.6) ρ_k 385 kg/m³ characteristic density of the timber raw material

CALCULATION EXAMPLE



- $\rho_{k,ref}$ 350 kg/m³ reference characteristic density of the timber raw material
 k_p 1.10 for softwood and $15^\circ \leq \alpha \leq 90^\circ$
 l_{ef} $\min\{l_{ef,1}; l_{ef,2}\} = 80$ mm
 k_{mod} 0.8 (SC1, duration of load medium-term)
 γ_M 1.30 (for connections in timber construction acc. to EN 1995-1-1, table 2.3)

$$F_{ax,90,Rd} = 13.1 \cdot 1.0 \cdot 1.06 \cdot \left(\frac{385}{350}\right)^{1.10} \cdot 8 \cdot 60 \cdot \frac{0.8}{1.30} = 4555 \text{ N}$$

design value of the screw tension resistance:

$$F_{tens,d} = \frac{F_{tens,k}}{\tilde{\alpha}_{M2}} = \frac{24100}{1.25} = 19280 \text{ N}$$

$F_{tens,k}$ 24100 N (acc. to ETA-22/0789:2023, table A6.1)

γ_{M2} 1.25 (for steel tension failure acc. to EN 1993-1-1:2014, section 6.1)

determination of the resistance of the screws

$$n_{90} = 2$$

$$F_{ax,Rd} = 2 \cdot \min\left\{\begin{matrix} 4555 \\ 19280 \end{matrix}\right\} = 2 \cdot 4555 = 9110 \text{ N}$$

verification

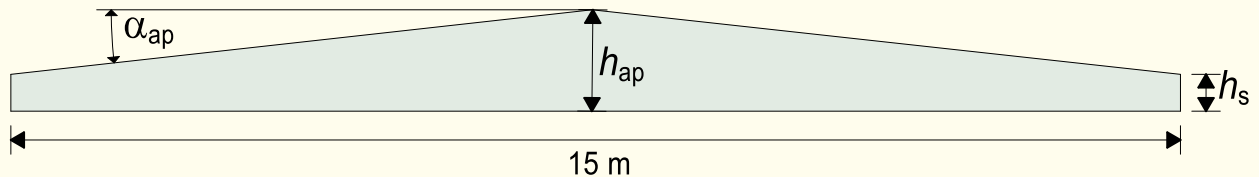
$$1.3 \cdot 10000 \cdot \left[3 \cdot \left(1 - \frac{120}{240}\right)^2 - 2 \cdot \left(1 - \frac{120}{240}\right)^3 \right] \leq 9110$$

$$6500 \text{ N} \leq 9110 \text{ N}$$

verification fulfilled (71 %)

REINFORCEMENT

A.3.5 reinforcement of a double tapered beam



DETAILS

service class SC1

loadingbending moment $M_{ap,d} = 375$ kNm

(duration of load medium-term)

construction element

glue laminated timber GL24h

 $h_{ap} = 820$ mm, $h_s = 300$ mm, $b = 160$ mm, $\alpha_{ap} = 4^\circ$ Wood Screw C-FT-12x700/6805 screws, $a_1 = 250$ mmload bearing capacity (tension perpendicular to grain) in the apex zone without reinforcement

The verification is made acc. to EN 1995-1-1, section 6.4.3.

$$\sigma_{t,90,d} \leq k_{dis} \cdot k_{vol} \cdot f_{t,90,d}$$

$$\sigma_{t,90,d} = k_p \cdot \frac{6 \cdot M_{ap,d}}{b \cdot h_{ap}^2}$$

$$k_p = k_5 + k_6 \cdot \left(\frac{h_{ap}}{r} \right) + k_7 \cdot \left(\frac{h_{ap}}{r} \right)^2$$

This term is omitted because it is
a beam with a straight lower edge

CALCULATION EXAMPLE



$$k_5 = 0.2 \cdot \tan(\alpha_{ap}) = 0.2 \cdot \tan(4^\circ) = 0.0140$$

$$k_p = k_5 = 0.0140$$

$$\sigma_{t,90,d} = 0.0140 \cdot \frac{6 \cdot 375 \cdot 10^6}{160 \cdot 820^2} = 0.292 \text{ N/mm}^2$$

k_{dis} 1.4 for double tapered beams with straight lower edge

V volume of the apex zone loaded in tension perpendicular to grain [m³]

$$V = \min \left\{ \frac{V_{ap}}{\frac{2}{3} \cdot V_b} \right\} = \min \left\{ \begin{array}{l} h_{ap}^2 \cdot [1 - 2 \cdot 0.25 \cdot \tan(\alpha_{ap})] \cdot b \cdot 10^{-9} \\ \frac{2}{3} \cdot \frac{h_{ap} - h_s}{2} \cdot b \cdot L \cdot 10^{-9} \end{array} \right\}$$

$$V = \min \left\{ \begin{array}{l} 820^2 \cdot [1 - 2 \cdot 0.25 \cdot \tan(4)] \cdot 160 \cdot 10^{-9} \\ \frac{2}{3} \cdot \frac{820 - 300}{2} \cdot 15000 \cdot 160 \cdot 10^{-9} \end{array} \right\} =$$

$$= \min \left\{ \begin{array}{l} 0.106 \text{ m}^3 \\ 0.416 \text{ m}^3 \end{array} \right\} = 0.106 \text{ m}^3$$

$$k_{ax} = \left(\frac{V_0}{V} \right)^2 \quad \text{for glue laminated timber}$$

$$k_{vol} = \left(\frac{V_0}{V} \right)^{0.2} = \left(\frac{0.01}{0.106} \right)^{0.2} = 0.624$$

$$f_{t,90,k} = 0.50 \text{ N/mm}^2 \quad (\text{acc. to EN 14080:2013})$$

$$f_{t,90,d} = f_{t,90,k} \cdot \frac{k_{mod}}{\gamma_M} = 0.50 \cdot \frac{0.8}{1.30} = 0.31 \text{ N/mm}^2$$

$$k_{dis} \cdot k_{val} \cdot f_{\alpha,90,d} = 1.4 \cdot 0.624 \cdot 0.308 = 0.269 \text{ N/mm}^2$$

verification

$$0.292 \leq 1.4 \cdot 0.624 \cdot 0.31$$

$$0.292 \text{ N/mm}^2 > 0.269 \text{ N/mm}^2$$

verification not fulfilled (109 %)

A reinforcement in the apex zone of the double tapered beam is required.

REINFORCEMENT

A.3.5 reinforcement of a double tapered beam

tension perpendicular to grain load bearing capacity in the apex zone with reinforcement

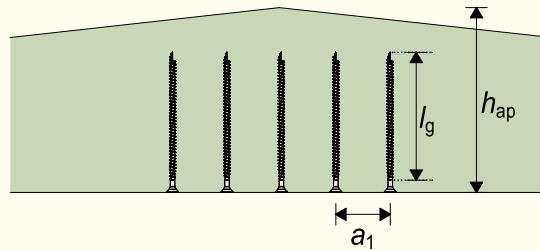
The verification is made acc. to prEN 1995-1-1:2025

$F_{t,90,d}$ action design value on each screw ($n = 5$)

$$F_{t,90,d} = \frac{\sigma_{t,90,d} \cdot b \cdot a_1}{n}$$

$$F_{t,90,d} = \frac{0.293 \cdot 160 \cdot 250}{5} = 11700 \text{ N}$$

determination of the load bearing capacity of the screws:



$$F_{ax,Rd} = n_{90} \cdot \min \left\{ \begin{array}{l} F_{ax,90,Rd} \\ F_{tens,d} \end{array} \right\}$$

design value of the withdrawal resistance:

$$F_{ax,90,Rd} = f_{ax,k,90} \cdot k_{ax} \cdot k_{sys} \cdot \left(\frac{\rho_k}{\rho_{k,ref}} \right)^{k_p} \cdot d \cdot l_{ef} \cdot \frac{k_{mod}}{\gamma_M}$$

$f_{ax,k,90}$ 11.2 N/mm² (acc. to ETA-22/0789:2023, table A6.1)

k_{ax} 1.0 for $30^\circ \leq \alpha \leq 90^\circ$

k_{sys} 1.15 for ≥ 6 penetrated layers (acc. to ETA-22/0789:2023, table A6.6)

ρ_k 380 kg/m³ characteristic density of the timber raw material

$\rho_{k,ref}$ 350 kg/m³ reference characteristic density of the timber raw material

k_p 1.10 for softwood and $15^\circ \leq \alpha \leq 90^\circ$

l_{ef} 280 mm

k_{mod} 0.8 (SC1, duration of load medium-term)

γ_M 1.30 (for connections in timber construction acc. to EN 1995-1-1, table 2.3)

$$F_{ax,90,Rd} = 11.2 \cdot 1.0 \cdot 1.15 \cdot \left(\frac{385}{350} \right)^{1.10} \cdot 12 \cdot 280 \cdot \frac{0.8}{1.30} = 29575 \text{ N}$$

CALCULATION EXAMPLE



design value of the screw tension resistance:

$$F_{\text{tens,d}} = \frac{F_{\text{tens,k}}}{\gamma_{M2}} = \frac{46700}{1.25} = 37360 \text{ N}$$

$F_{\text{tens,k}}$ 46700 N (acc. to ETA-22/0789:2023, table A6.1)

γ_{M2} 1.25 (for steel tension failure acc. to EN 1993-1-1:2014, section 6.1)

determination of the screw resistance

$$F_{\text{ax,Rd}} = \min \left\{ \begin{array}{l} 29575 \\ 37360 \end{array} \right\} = 29575 \text{ N}$$

verification

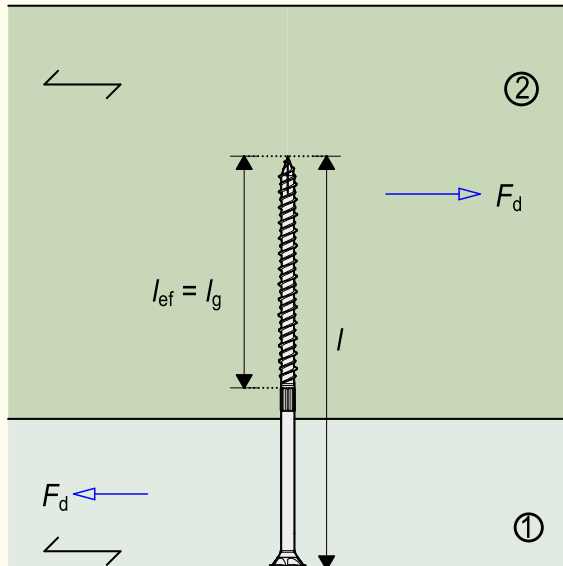
$$F_{t,90,d} \leq F_{Rd}$$

$$11700 \text{ N} \leq 29575 \text{ N}$$

verification fulfilled (40 %)

PARTIALLY THREADED SCREWS

B.1.1.1 general - connection between to timber elements ($\alpha = 90^\circ$, $\varepsilon = 0^\circ$)

**DETAILS**

service class SC1

loading

$F_{Ed} = 1500$ N per screw
(duration of load medium-term)

construction elements

construction element 1:

solid timber, C24, $t_1 = 30$ mm

construction element 2:

solid timber, C24

Wood Screw C-PT-8x180/100

$d = 8$ mm, $l = 180$ mm, $l_g = 100$ mm,

$d_k = 15$ mm, $l_{ef} = 100$ mm

spacing between screws

$a_1 = 250$ mm $\geq 25 \cdot d = 200$ mm $\rightarrow n_{ef} = n$

determination of embedment strength and yield moment

(acc. to ETA-22/0789:2023, section A.6.2.3)

 α 90° , axis-grain-angle ε 0° , load-grain-angle

$$f_{h,k} = k_\alpha \cdot k_\beta \cdot k_\varepsilon \cdot f_{h,k,ref}$$

$$k_\alpha = \frac{1}{2.5 \cdot \cos^2(\alpha) + \sin^2(\alpha)} = \frac{1}{2.5 \cdot \cos^2(90) + \sin^2(90)} = 1.0$$

 k_β 1.0

$$k_\varepsilon = k_{90} \cdot \cos^2(\varepsilon) + \sin^2(\varepsilon)$$

$$k_{90} = \begin{cases} 1.10 \text{ in the member of the head side} & \rightarrow k_{\varepsilon,1} = 1.10 \cdot \cos^2(0) + \sin^2(0) = 1.10 \\ 1.20 \text{ in the member of the tip side} & \rightarrow k_{\varepsilon,2} = 1.20 \cdot \cos^2(0) + \sin^2(0) = 1.20 \end{cases}$$

 ρ_k 350 kg/m³ characteristic density of the timber element $f_{h,k,ref}$ characteristic reference embedment strength of non-predrilled timber elements

$$f_{h,k,ref} = 0.082 \cdot \rho_k \cdot d^{-0.3} = 0.082 \cdot 350 \cdot 8^{-0.3} = 15.4 \text{ N/mm}^2$$

$$f_{h,k,1} = 1.0 \cdot 1.0 \cdot 1.1 \cdot 15.4 = 16.9 \text{ N/mm}^2$$

$$f_{h,k,2} = 1.0 \cdot 1.0 \cdot 1.2 \cdot 15.4 = 18.5 \text{ N/mm}^2$$

$M_{\gamma,Rk}$ 22.6 Nm \equiv 22600 Nmm, characteristic yield moment (acc. to ETA-22/0789:2023, table A6.2)

TIMBER-TO-TIMBER CONNECTION CALCULATION EXAMPLE

determination of the load bearing capacity of the single shear timber to timber connection

(acc. to EN 1995-1-1, section 8.2.2 with equation 8.6)

$$\beta = \frac{f_{h,k,2}}{f_{h,k,1}} = \frac{18.5}{16.9} = 1.09$$

$$F_{V,Rd} = \min \left\{ \begin{array}{l} F_{V,Rd,a} \quad (a) \\ F_{V,Rd,b} \quad (b) \\ F_{V,Rd,c} + \Delta F_{V,Rd} \quad (c) \\ F_{V,Rd,d} + \Delta F_{V,Rd} \quad (d) \\ F_{V,Rd,e} + \Delta F_{V,Rd} \quad (e) \\ F_{V,Rd,f} + \Delta F_{V,Rd} \quad (f) \end{array} \right.$$

load bearing capacity of the single shear timber to timber connection:

$$F_{V,Rk,a} = f_{h,1,k} \cdot t_1 \cdot d = 16.92 \cdot 30 \cdot 8 = 4060 \text{ N} \quad (a)$$

$$F_{V,Rk,b} = f_{h,2,k} \cdot t_2 \cdot d = 18.46 \cdot 150 \cdot 8 = 22147 \text{ N} \quad (b)$$

$$F_{V,Rk,c} = \frac{f_{h,1,k} \cdot t_1 \cdot d}{1 + \beta} \cdot \left[\sqrt{\beta + 2 \cdot \beta^2 \cdot \left[1 + \frac{t_2}{t_1} + \left(\frac{t_2}{t_1} \right)^2 \right] + \beta^3 \cdot \left(\frac{t_2}{t_1} \right)^2} - \beta \cdot \left(1 + \frac{t_2}{t_1} \right) \right]$$

$$= \frac{16.9 \cdot 30 \cdot 8}{1 + 1.09} \cdot \left[\sqrt{1.09 + 2 \cdot 1.09^2 \cdot \left[1 + \frac{150}{30} + \left(\frac{150}{30} \right)^2 \right] + 1.09^3 \cdot \left(\frac{150}{30} \right)^2} - 1.09 \cdot \left(1 + \frac{150}{30} \right) \right]$$

$$= 7403 \text{ N} \quad (c)$$

$$F_{V,Rk,d} = 1.05 \cdot \frac{f_{h,1,k} \cdot t_1 \cdot d}{2 + \beta} \cdot \left[\sqrt{2 \cdot \beta \cdot (1 + \beta) + \frac{4 \cdot \beta \cdot (2 + \beta) \cdot M_{y,Rk}}{f_{h,1,k} \cdot d \cdot t_1^2}} - \beta \right]$$

$$= 1.05 \cdot \frac{16.9 \cdot 30 \cdot 8}{2 + 1.09} \cdot \left[\sqrt{2 \cdot 1.09 \cdot (1 + 1.09) + \frac{4 \cdot 1.09 \cdot (2 + 1.09) \cdot 22600}{16.9 \cdot 8 \cdot 30^2}} - 1.09 \right]$$

$$= 2161 \text{ N} \quad (d)$$

$$F_{V,Rk,e} = 1.05 \cdot \frac{f_{h,1,k} \cdot t_2 \cdot d}{1 + 2 \cdot \beta} \cdot \left[\sqrt{2 \cdot \beta^2 \cdot (1 + \beta) + \frac{4 \cdot \beta \cdot (1 + 2 \cdot \beta) \cdot M_{y,Rk}}{f_{h,1,k} \cdot d \cdot t_2^2}} - \beta \right]$$

$$= 1.05 \cdot \frac{16.9 \cdot 150 \cdot 8}{1 + 2 \cdot 1.09} \cdot \left[\sqrt{2 \cdot 1.09^2 \cdot (1 + 1.09) + \frac{4 \cdot 1.09 \cdot (1 + 2 \cdot 1.09) \cdot 22600}{16.9 \cdot 8 \cdot 150^2}} - 1.09 \right]$$

$$= 7791 \text{ N} \quad (e)$$

PARTIALLY THREADED SCREWS

B.1.1.1 general - connection between to timber elements ($\alpha = 90^\circ, \varepsilon = 0^\circ$)

$$\begin{aligned}
 F_{V,Rk,f} &= 1.15 \cdot \sqrt{\frac{2 \cdot \beta}{1 + \beta}} \cdot \sqrt{2 \cdot M_{y,Rk} \cdot f_{h,1,k} \cdot d} \\
 &= 1.15 \cdot \sqrt{\frac{2 \cdot 1.09}{1 + 1.09}} \cdot \sqrt{2 \cdot 22600 \cdot 16.9 \cdot 8} \\
 &= 2906 \text{ N} \quad (f)
 \end{aligned}$$

load bearing capacity of the rope effect:

$$\Delta F_{V,Rd} = \min \left\{ F_{V,Rd}; \frac{F_{ax,Rd}}{4} \right\}$$

$$F_{ax,Rd} = \min \left\{ \begin{array}{l} \text{head pull-through resistance in element 1} \\ \text{withdrawal resistance in element 2} \\ \text{screw tension resistance} \end{array} \right\}$$

determination of head pull-through resistance in element 1:

$$F_{ax,Rk,1} = f_{head,k} \cdot d_h^2 \cdot \left(\frac{\rho_k}{\rho_{k,ref}} \right)^{0.8}$$

$f_{head,k}$ 12.4 N/mm² (acc. to ETA- 22/0789:2023, table A6.7)
 ρ_k 350 kg/m³ characteristic density of the timber raw material
 $\rho_{k,ref}$ 350 kg/m³ reference characteristic density of the timber raw material
 $F_{ax,Rk,1} = 12.4 \cdot 15^2 \cdot 1.0 = 2790 \text{ N}$

determination of withdrawal resistance in element 2:

$$F_{ax,Rk,2} = f_{ax,k,90} \cdot k_{ax} \cdot k_{sys} \cdot \left(\frac{\rho_k}{\rho_{k,ref}} \right)^{k_p} \cdot d \cdot l_{ef}$$

$f_{ax,k,90}$ 10.9 N/mm³ (acc. to ETA-22/0789:2023, table A6.2)
 k_{ax} 1.0 for $30^\circ \leq \alpha \leq 90^\circ$
 k_{sys} 1.00 for solid timber
 ρ_k 350 kg/m³ characteristic density of the timber raw material
 $\rho_{k,ref}$ 350 kg/m³ reference characteristic density of the timber raw material
 k_p 1.10 for softwood and $15^\circ \leq \alpha \leq 90^\circ$
 l_{ef} 100 mm
 $F_{ax,Rk,2} = 10.9 \cdot 1.0 \cdot 1.00 \cdot \left(\frac{350}{350} \right)^{1.10} \cdot 8 \cdot 100 = 8720 \text{ N}$

TIMBER-TO-TIMBER CONNECTION CALCULATION EXAMPLE

determination of screw tension resistance:

$$F_{\text{tens,k}} = 23300 \text{ N (acc. to ETA- 22/0789:2023, table A6.2)}$$

design value of the load bearing capacity of the single screw:

$$F_{\text{ax,Rd}} = \min \left\{ \begin{array}{l} F_{\text{head,Rd},1} \\ F_{\text{ax,Rd},2} \\ F_{\text{tens,d}} \end{array} \right\} = \min \left\{ \begin{array}{l} F_{\text{head,Rk},1} \cdot k_{\text{mod}} / \gamma_{\text{M}} \\ F_{\text{ax,Rk},2} \cdot k_{\text{mod}} / \gamma_{\text{M}} \\ F_{\text{tens,k}} / \gamma_{\text{M2}} \end{array} \right\}$$

$$k_{\text{mod}} = 0.8 \text{ (SC1, duration of load medium-term)}$$

$$\gamma_{\text{M}} = 1.30 \text{ (for connections in timber construction acc. to EN 1995-1-1, table 2.3)}$$

$$\gamma_{\text{M2}} = 1.25 \text{ (for steel tension failure acc. to EN 1993-1-1:2014, section 6.1)}$$

$$F_{\text{ax,Rd}} = \min \left\{ \begin{array}{l} 2790 \cdot 0.8 / 1.30 \\ 8720 \cdot 0.8 / 1.30 \\ 23300 / 1.25 \end{array} \right\} = \min \left\{ \begin{array}{l} 1717 \\ 5366 \\ 18080 \end{array} \right\} = 1717 \text{ N}$$

design value of the load bearing capacity of the rope effect:

$$\Delta F_{\text{V,Rd}} = \min \left\{ \begin{array}{l} F_{\text{v,Rd}} \\ 1717 / 4 \end{array} \right\} = \min \left\{ \begin{array}{l} F_{\text{v,Rd}} \\ 429 \text{ N} \end{array} \right\}$$

design value of the load bearing capacity of the single shear timber to timber connection:

$$F_{\text{V,Rd}} = \min \left\{ \begin{array}{l} F_{\text{V,Rk,a}} \cdot k_{\text{mod}} / \gamma_{\text{M}} \quad (\text{a}) \\ F_{\text{V,Rk,b}} \cdot k_{\text{mod}} / \gamma_{\text{M}} \quad (\text{b}) \\ F_{\text{V,Rk,c}} \cdot k_{\text{mod}} / \gamma_{\text{M}} + \Delta F_{\text{V,Rd}} \quad (\text{c}) \\ F_{\text{V,Rk,d}} \cdot k_{\text{mod}} / \gamma_{\text{M}} + \Delta F_{\text{V,Rd}} \quad (\text{d}) \\ F_{\text{V,Rk,e}} \cdot k_{\text{mod}} / \gamma_{\text{M}} + \Delta F_{\text{V,Rd}} \quad (\text{e}) \\ F_{\text{V,Rk,f}} \cdot k_{\text{mod}} / \gamma_{\text{M}} + \Delta F_{\text{V,Rd}} \quad (\text{f}) \end{array} \right\} = \min \left\{ \begin{array}{l} 4060 \cdot 0.8 / 1.30 \quad (\text{a}) \\ 22147 \cdot 0.8 / 1.30 \quad (\text{b}) \\ 7408 \cdot 0.8 / 1.30 + 429 \quad (\text{c}) \\ 2161 \cdot 0.8 / 1.30 + 429 \quad (\text{d}) \\ 7791 \cdot 0.8 / 1.30 + 429 \quad (\text{e}) \\ 2906 \cdot 0.8 / 1.30 + 429 \quad (\text{f}) \end{array} \right\}$$

$$= \min \left\{ \begin{array}{l} 2499 \quad (\text{a}) \\ 13629 \quad (\text{b}) \\ 4988 \quad (\text{c}) \\ 1759 \quad (\text{d}) \\ 5224 \quad (\text{e}) \\ 2217 \quad (\text{f}) \end{array} \right\} = 1759 \text{ N}$$

verification

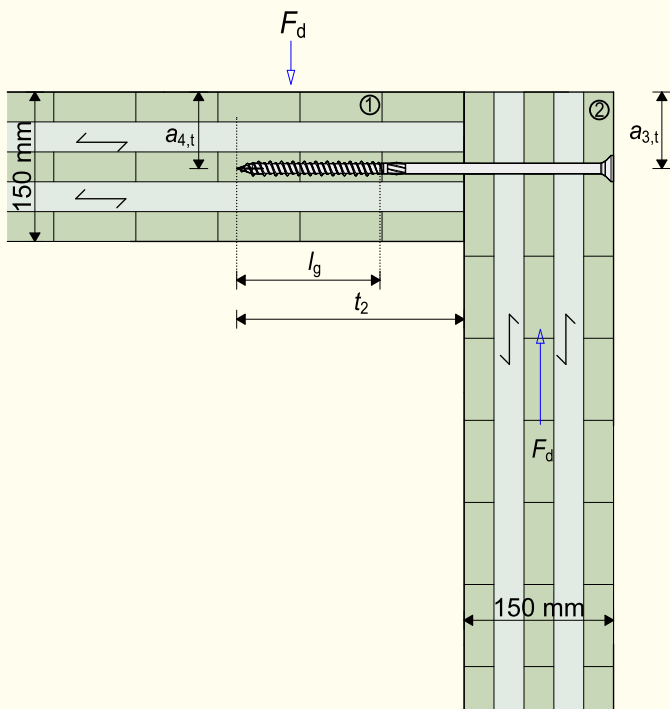
$$F_{\text{Ed}} \leq F_{\text{V,Rd}}$$

$$1500 \text{ N} \leq 1759 \text{ N}$$

verification fulfilled (85 %)

PARTIALLY THREADED SCREWS

B.1.1.2 CLT-wall corner



DETAILS

service class SC1

loading

$F_{Ed} = 1500$ N per screw
(duration of load short-term / instantaneous according to EN 1995-1-1)

construction elements

construction element 1 and 2:
cross laminated timber
 $t = 150$ mm, $\rho_k = 385$ kg/m³

Wood Screw C-PT-8x240/100

$d = 8$ mm, $l = 240$ mm, $l_g = l_{ef} = 100$ mm
 $d_k = 15$ mm

minimum spacing and minimum penetration length

(acc. to ETA-22/0789:2023, table A6.5)

narrow face: $a_{4,t} = 75$ mm $\geq 5 \cdot d = 5 \cdot 8 = 40$ mm \rightarrow OKwide face: $a_{3,c} = 75$ mm $\geq 6 \cdot d = 6 \cdot 8 = 48$ mm \rightarrow OKnarrow face: $t_2 \triangleq l_{min} = 90$ mm $\geq 10 \cdot d = 10 \cdot 8 = 80$ mm \rightarrow OKdetermination of embedment strength and yield moment

(acc. to ETA-22/0789:2023, section A.6.2.3)

narrow face: $f_{h,1,k} = 20 \cdot d^{-0.5} = 20 \cdot 8^{-0.5} = 7.1$ N/mm²

wide face:

 α 90°, axis-grain-angle ε 0°, load-grain-angle

$$f_{h,k} = k_{\alpha} \cdot k_{\beta} \cdot k_{\varepsilon} \cdot f_{h,k,ref}$$

$$k_{\alpha} = \frac{1}{2.5 \cdot \cos^2(\alpha) + \sin^2(\alpha)} = \frac{1}{2.5 \cdot \cos^2(90) + \sin^2(90)} = 1.0$$

$$k_{\beta} = 1.0$$

$$k_{\varepsilon} = k_{90} \cdot \cos^2(\varepsilon) + \sin^2(\varepsilon)$$

$$k_{90} = 1.10 \text{ in the member of the head side} \rightarrow k_{\varepsilon} = 1.10 \cdot \cos^2(90) + \sin^2(90) = 1.00$$

 ρ_k 385 kg/m³ characteristic density of the timber element $f_{h,k,ref}$ characteristic reference embedment strength of non-predrilled timber elements

TIMBER-TO-TIMBER CONNECTION CALCULATION EXAMPLE

$$f_{h,k,ref} = 0.082 \cdot \rho_k \cdot d^{-0.3} = 0.082 \cdot 385 \cdot 8^{-0.3} = 16.9 \text{ N/mm}^2$$

$$f_{h,k,2} = 1.0 \cdot 1.0 \cdot 1.0 \cdot 16.9 = 16.9 \text{ N/mm}^2$$

$$M_{y,Rk} = 22.6 \text{ Nm} \equiv 22600 \text{ Nmm, characteristic yield moment (acc. to ETA- 22/0789:2023, table A6.2)}$$

determination of the load bearing capacity of the single shear timber-to-timber connection

(acc. to EN 1995-1-1, section 8.2.2 with equation 8.6)

$$\beta = \frac{f_{h,2,k}}{f_{h,1,k}} = \frac{16.9}{7.1} = 2.4$$

$$F_{V,Rd} = \min \left\{ \begin{array}{l} F_{V,Rd,a} \quad \text{(a)} \\ F_{V,Rd,b} \quad \text{(b)} \\ F_{V,Rd,c} + \Delta F_{V,Rd} \quad \text{(c)} \\ F_{V,Rd,d} + \Delta F_{V,Rd} \quad \text{(d)} \\ F_{V,Rd,e} + \Delta F_{V,Rd} \quad \text{(e)} \\ F_{V,Rd,f} + \Delta F_{V,Rd} \quad \text{(f)} \end{array} \right.$$

load bearing capacity of the single shear timber-to-timber connection:

$$F_{V,Rk,a} = f_{h,1,k} \cdot t_1 \cdot d = 7.1 \cdot 150 \cdot 8 = 8485 \text{ N} \quad \text{(a)}$$

$$F_{V,Rk,b} = f_{h,2,k} \cdot t_2 \cdot d = 16.9 \cdot 90 \cdot 8 = 12181 \text{ N} \quad \text{(b)}$$

$$\begin{aligned} F_{V,Rk,c} &= \frac{f_{h,1,k} \cdot t_1 \cdot d}{1 + \beta} \cdot \left[\sqrt{\beta + 2 \cdot \beta^2 \cdot \left[1 + \frac{t_2}{t_1} + \left(\frac{t_2}{t_1} \right)^2 \right] + \beta^3 \cdot \left(\frac{t_2}{t_1} \right)^2} - \beta \cdot \left(1 + \frac{t_2}{t_1} \right) \right] \\ &= \frac{7.1 \cdot 150 \cdot 8}{1 + 2.4} \cdot \left[\sqrt{1.0 + 2 \cdot 2.4^2 \cdot \left[1 + \frac{90}{150} + \left(\frac{90}{150} \right)^2 \right] + 2.4^3 \cdot \left(\frac{90}{150} \right)^2} - 2.4 \cdot \left(1 + \frac{90}{150} \right) \right] \\ &= 4070 \text{ N} \quad \text{(c)} \end{aligned}$$

$$\begin{aligned} F_{V,Rk,d} &= 1.05 \cdot \frac{f_{h,1,k} \cdot t_1 \cdot d}{2 + \beta} \cdot \left[\sqrt{2 \cdot \beta \cdot (1 + \beta) + \frac{4 \cdot \beta \cdot (2 + \beta) \cdot M_{y,Rk}}{f_{h,1,k} \cdot d \cdot t_1^2}} - \beta \right] \\ &= 1.05 \cdot \frac{7.1 \cdot 150 \cdot 8}{2 + 2.4} \cdot \left[\sqrt{2 \cdot 2.4 \cdot (1 + 2.4) + \frac{4 \cdot 2.4 \cdot (2 + 2.4) \cdot 22600}{7.1 \cdot 8 \cdot 150^2}} - 2.4 \right] \\ &= 3505 \text{ N} \quad \text{(d)} \end{aligned}$$

$$\begin{aligned} F_{V,Rk,e} &= 1.05 \cdot \frac{f_{h,1,k} \cdot t_2 \cdot d}{1 + 2 \cdot \beta} \cdot \left[\sqrt{2 \cdot \beta^2 \cdot (1 + \beta) + \frac{4 \cdot \beta \cdot (1 + 2 \cdot \beta) \cdot M_{y,Rk}}{f_{h,1,k} \cdot d \cdot t_2^2}} - \beta \right] \\ &= 1.05 \cdot \frac{7.1 \cdot 90 \cdot 8}{1 + 2 \cdot 2.4} \cdot \left[\sqrt{2 \cdot 2.4^2 \cdot (1 + 2.4) + \frac{4 \cdot 2.4 \cdot (1 + 2 \cdot 2.4) \cdot 22600}{7.1 \cdot 8 \cdot 90^2}} - 2.4 \right] \\ &= 3747 \text{ N} \quad \text{(e)} \end{aligned}$$

PARTIALLY THREADED SCREWS

B.1.1.2 CLT-wall corner

$$\begin{aligned}
 F_{V,Rk,f} &= 1.15 \cdot \sqrt{\frac{2 \cdot \beta}{1 + \beta}} \cdot \sqrt{2 \cdot M_{y,Rk} \cdot f_{h,1,k} \cdot d} \\
 &= 1.15 \cdot \sqrt{\frac{2 \cdot 2.4}{1 + 2.4}} \cdot \sqrt{2 \cdot 22600 \cdot 7.1 \cdot 8} \\
 &= 2184 \text{ N (f)}
 \end{aligned}$$

load bearing capacity of the rope effect:

$$\Delta F_{V,Rd} = \min \left\{ F_{V,Rd,i}, \frac{F_{ax,Rd}}{4} \right\}$$

$$F_{ax,Rd} = \min \left\{ \begin{array}{l} \text{head pull-through resistance in element 1} \\ \text{withdrawal resistance in element 2} \\ \text{screw tension resistance} \end{array} \right\}$$

determination of head pull-through resistance in element 1:

$$F_{ax,Rk,1} = f_{head,k} \cdot d_h^2 \cdot \left(\frac{\rho_k}{\rho_{k,ref}} \right)^{0.8}$$

$f_{head,k}$ 12.4 N/mm² (acc. to ETA- 22/0789:2023, table A6.7)
 ρ_k 385 kg/m³ characteristic density of the timber raw material
 $\rho_{k,ref}$ 350 kg/m³ reference characteristic density of the timber raw material

$$F_{ax,Rk,1} = 12.4 \cdot 15^2 \cdot \left(\frac{385}{350} \right)^{0.8} = 3011 \text{ N}$$

determination of withdrawal resistance in element 2:

$$F_{ax,Rk,2} = f_{ax,k,90} \cdot k_{ax} \cdot k_{sys} \cdot \left(\frac{\rho_k}{\rho_{k,ref}} \right)^{k_p} \cdot d \cdot l_{ef}$$

$f_{ax,k,90}$ 10.9 N/mm³ (acc. to ETA- 22/0789:2023, table A6.2)
 k_{ax} 1.0 for $30^\circ \leq \alpha \leq 90^\circ$
 k_{sys} 1.00 for solid timber
 ρ_k 350 kg/m³ characteristic density of the timber raw material
 $\rho_{k,ref}$ 350 kg/m³ reference characteristic density of the timber raw material
 k_p 1.10 for softwood and $15^\circ \leq \alpha \leq 90^\circ$
 l_{ef} 100 mm

$$F_{ax,Rk,2} = 10.9 \cdot 1.0 \cdot 1.00 \cdot \left(\frac{350}{350} \right)^{1.10} \cdot 8 \cdot 100 = 8720 \text{ N}$$

determination of screw tension resistance:

$$F_{tens,k} = 23300 \text{ N (acc. to ETA- 22/0789:2023, table A6.2)}$$

TIMBER-TO-TIMBER CONNECTION CALCULATION EXAMPLE

design value of the load bearing capacity of the single screw:

$$F_{ax,Rd} = \min \left\{ \begin{array}{l} F_{head,Rd,1} \\ F_{ax,Rd,2} \\ F_{tens,d} \end{array} \right\} = \min \left\{ \begin{array}{l} F_{head,Rk,1} \cdot k_{mod} / \gamma_M \\ F_{ax,Rk,2} \cdot k_{mod} / \gamma_M \\ F_{tens,k} / \gamma_{M2} \end{array} \right\}$$

k_{mod} 0.9 (SC1, duration of load short-term / instantaneous according to EN 1995-1-1)

γ_M 1.30 (for connections in timber construction acc. to EN 1995-1-1, table 2.3)

γ_{M2} 1.25 (for steel tension failure acc. to EN 1993-1-1:2014, section 6.1)

$$F_{ax,Rd} = \min \left\{ \begin{array}{l} 3011 \cdot 0.9 / 1.30 \\ 8720 \cdot 0.9 / 1.30 \\ 23300 / 1.25 \end{array} \right\} = \min \left\{ \begin{array}{l} 2085 \\ 6037 \\ 18080 \end{array} \right\} = 2085 \text{ N}$$

design value of the load bearing capacity of the rope effect:

$$\Delta F_{V,Rd} = \min \left\{ \begin{array}{l} F_{v,Rd,i} \\ 2085 / 4 \end{array} \right\} = \min \left\{ \begin{array}{l} F_{v,Rd,i} \\ 521 \text{ N} \end{array} \right\}$$

design value of the load bearing capacity of the single shear timber-to-timber connection:

$$F_{V,Rd} = \min \left\{ \begin{array}{l} F_{V,Rk,a} \cdot k_{mod} / \gamma_M \quad (a) \\ F_{V,Rk,b} \cdot k_{mod} / \gamma_M \quad (b) \\ F_{V,Rk,c} \cdot k_{mod} / \gamma_M + \Delta F_{V,Rd} \quad (c) \\ F_{V,Rk,d} \cdot k_{mod} / \gamma_M + \Delta F_{V,Rd} \quad (d) \\ F_{V,Rk,e} \cdot k_{mod} / \gamma_M + \Delta F_{V,Rd} \quad (e) \\ F_{V,Rk,f} \cdot k_{mod} / \gamma_M + \Delta F_{V,Rd} \quad (f) \end{array} \right\} = \min \left\{ \begin{array}{l} 8485 \cdot 0.9 / 1.30 \quad (a) \\ 12181 \cdot 0.9 / 1.30 \quad (b) \\ 4070 \cdot 0.9 / 1.30 + 521 \quad (c) \\ 3505 \cdot 0.9 / 1.30 + 521 \quad (d) \\ 3747 \cdot 0.9 / 1.30 + 521 \quad (e) \\ 2184 \cdot 0.9 / 1.30 + 521 \quad (f) \end{array} \right\}$$

$$= \min \left\{ \begin{array}{l} 5874 \quad (a) \\ 8433 \quad (b) \\ 3339 \quad (c) \\ 2948 \quad (d) \\ 3115 \quad (e) \\ 2033 \quad (f) \end{array} \right\} = 2033 \text{ N}$$

verification

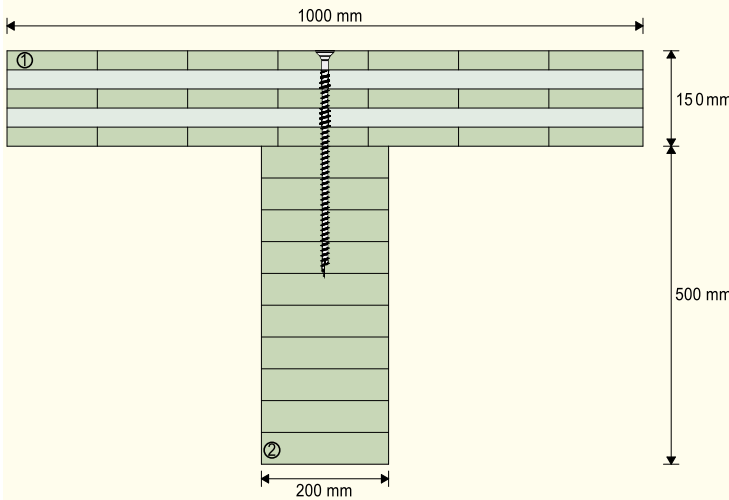
$$F_{Ed} \leq F_{V,Rd}$$

$$1500 \text{ N} \leq 2033 \text{ N}$$

verification fulfilled (74%)

PARTIALLY THREADED SCREWS

B.1.2.1 mechanically jointed ribbed slab



DETAILS

service class SC1

loading

shear force $V_{Ed} = 35000$ N

(duration of load medium-term)

construction elements

construction element 1: cross laminated timber

 $E_1 = 11600$ N/mm², $\rho_{mean,1} = 385$ kg/m³

construction element 2: glue laminated timber GL24h,

 $E_2 = 11500$ N/mm², $\rho_{mean,2} = 385$ kg/m³

effective width: 1000 mm

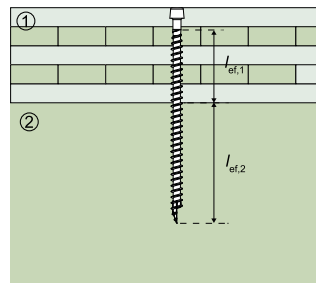
span: 6000 mm

screw $s_1 = 250$ mm spacing between screws
($n = 4$ per meter)**variant 1:**screw perpendicular to grain $\alpha = 90^\circ$

laterally loaded screws

Wood Screw

CY-FT-8x300/290

 $d = 8$ mm, $l_g = 290$ mm, $l_{ef,1} = 140$ mm, $l_{ef,2} = 150$ mm**variant 2:**

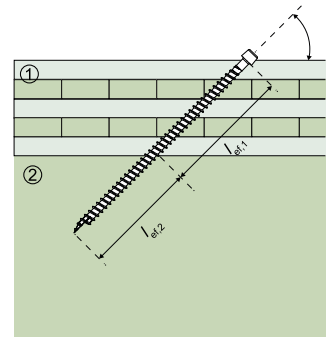
screws at an angle

 $\alpha = 45^\circ$ to grain

mainly axially loaded screws

Wood Screw

CY-FT-8x400/390

 $d = 8$ mm, $l_g = 400$ mm, $l_{ef,1} = 194$ mm, $l_{ef,2} = 196$ mm**variant 1: screw perpendicular to grain $\alpha = 90^\circ$** determination of the load bearing capacity of the flexible jointed beam

The load bearing capacity of the flexible jointed beam is determined acc. to EN 1995-1-1:2014 annex B.

 $(EI)_{ef}$ effective bending stiffness

$$(EI)_{ef} = \sum_{i=1}^2 (E_i \cdot I_i + \gamma_i E_i A_i a_i^2)$$

$$A_1 = b_1 \cdot h_1 = 1000 \cdot 150 = 150000 \text{ mm}^2$$

$$I_1 = \frac{b_1 \cdot h_1^3}{12} = \frac{1000 \cdot 150^3}{12} = 60750000 \text{ mm}^4$$

$$A_2 = b_2 \cdot h_2 = 200 \cdot 500 = 100000 \text{ mm}^2$$

$$I_2 = \frac{b_2 \cdot h_2^3}{12} = \frac{200 \cdot 500^3}{12} = 20.8 \cdot 10^8 \text{ mm}^4$$

$$\gamma_2 = 1$$

$$K_1 = \frac{2}{3} \cdot K_{ser} = \frac{2}{3} \cdot \rho_{mean}^{1.5} \cdot \frac{d}{23} = \frac{2}{3} \cdot 385^{1.5} \cdot \frac{8}{23} = 1752 \text{ N/mm}$$

TIMBER-TO-TIMBER CONNECTION CALCULATION EXAMPLE

$$\gamma_1 = \frac{1}{1 + \pi^2 \cdot \frac{E_1 \cdot A_1 \cdot s_1}{K_1 \cdot I^2}}$$

$$\gamma_1 = \frac{1}{1 + \pi^2 \cdot \frac{11600 \cdot 150000 \cdot 250}{1752 \cdot 6000^2}} = 0.0144$$

$$a_2 = \frac{\gamma_1 \cdot E_1 \cdot A_1 \cdot (h_1 + h_2)}{2 \cdot \sum_{i=1}^2 \gamma_i \cdot E_i \cdot A_i} = \frac{0.0145 \cdot 11600 \cdot 150000 \cdot (150 + 500)}{2 \cdot (0.0145 \cdot 11600 \cdot 150000 + 1 \cdot 11500 \cdot 100000)} = 7 \text{ mm}$$

$$a_1 = \frac{h_1 + h_2}{2} - a_2 = \frac{150 + 500}{2} - 7 = 318 \text{ mm}$$

$$(EI)_{\text{ef}} = 11600 \cdot 60750000 + 0.0145 \cdot 11600 \cdot 150000 \cdot 318^2 + 11500 \cdot 20.8 \cdot 10^8 + 1 \cdot 11500 \cdot 100000 \cdot 7^2 = 2.72 \cdot 10^{13} \text{ Nmm}^2$$

action design value of the single screw:

$$F_{\text{Ed},1} = \frac{\gamma_1 \cdot E_1 \cdot A_1 \cdot a_1 \cdot s_1}{(EI)_{\text{ef}}} \cdot V_{\text{Ed}} = \frac{0.0145 \cdot 11600 \cdot 150000 \cdot 318 \cdot 250}{2.72 \cdot 10^{13}} \cdot 35000 = 2574 \text{ N}$$

determination of embedment strength and yield moment

(acc. to ETA-22/0789:2023, section A.6.2.3)

α 90°, axis-grain-angle

ε 0°, load-grain-angle

$$f_{h,k} = k_\alpha \cdot k_\beta \cdot k_\varepsilon \cdot f_{h,k,\text{ref}}$$

$$k_\alpha = \frac{1}{2.5 \cdot \cos^2(\alpha) + \sin^2(\alpha)} = \frac{1}{2.5 \cdot \cos^2(90) + \sin^2(90)} = 1.0$$

$$k_\beta = 1.0$$

$$k_\varepsilon = k_{90} \cdot \cos^2(\varepsilon) + \sin^2(\varepsilon)$$

$$k_{90} = \begin{cases} 1.10 \text{ in the member of the head side} & \rightarrow k_{\varepsilon,1} = 1.10 \cdot \cos^2(0) + \sin^2(0) = 1.10 \\ 1.20 \text{ in the member of the tip side} & \rightarrow k_{\varepsilon,1} = 1.20 \cdot \cos^2(0) + \sin^2(0) = 1.20 \end{cases}$$

FULLY THREADED SCREWS

B.1.2.1 mechanically jointed ribbed slab

ρ_k 385 kg/m³ characteristic density of the timber element
 $f_{h,k,ref}$ characteristic reference embedment strength of non-predrilled timber elements (acc. to ETA-22/0789:2023, section A.6.2.3)

$$f_{h,k,ref} = 0.082 \cdot \rho_k \cdot d_{ef}^{-0.3} = 0.082 \cdot 385 \cdot 8^{-0.3} = 16.9 \text{ N/mm}^2$$

$$f_{h,k,1} = 1.0 \cdot 1.0 \cdot 1.1 \cdot 16.9 = 18.6 \text{ N/mm}^2$$

$$f_{h,k,2} = 1.0 \cdot 1.0 \cdot 1.2 \cdot 16.9 = 20.3 \text{ N/mm}^2$$

$M_{y,Rk}$ 20.3 Nm \equiv 20300 Nmm, characteristic yield moment (acc. to ETA-22/0789:2023, table A6.1)

determination of the load bearing capacity of the single shear timber to timber connection

(acc. to EN 1995-1-1, section 8.2.2 with equation 8.6)

$$F_{V,Rd} = \min \left\{ \begin{array}{l} F_{V,Rd,a} \quad (a) \\ F_{V,Rd,b} \quad (b) \\ F_{V,Rd,c} + \Delta F_{V,Rd} \quad (c) \\ F_{V,Rd,d} + \Delta F_{V,Rd} \quad (d) \\ F_{V,Rd,e} + \Delta F_{V,Rd} \quad (e) \\ F_{V,Rd,f} + \Delta F_{V,Rd} \quad (f) \end{array} \right\}$$

$$F_{V,Rk,a} = f_{h,1,k} \cdot t_1 \cdot d = 18.6 \cdot 150 \cdot 8 = 22332 \text{ N} \quad (a)$$

$$F_{V,Rk,b} = f_{h,2,k} \cdot t_2 \cdot d = 20.3 \cdot 150 \cdot 8 = 24362 \text{ N} \quad (b)$$

$$\beta = \frac{f_{h,k,2}}{f_{h,k,1}} = \frac{20.3}{18.6} = 1.09$$

$$\begin{aligned} F_{V,Rk,c} &= \frac{f_{h,1,k} \cdot t_1 \cdot d}{1 + \beta} \cdot \left[\sqrt{\beta + 2 \cdot \beta^2 \cdot \left[1 + \frac{t_2}{t_1} + \left(\frac{t_2}{t_1} \right)^2 \right] + \beta^3 \cdot \left(\frac{t_2}{t_1} \right)^2} - \beta \cdot \left(1 + \frac{t_2}{t_1} \right) \right] \\ &= \frac{18.6 \cdot 150 \cdot 8}{1 + 1.09} \cdot \left[\sqrt{1.09 + 2 \cdot 1.09^2 \cdot \left[1 + \frac{150}{30} + \left(\frac{150}{30} \right)^2 \right] + 1.09^3 \cdot \left(\frac{150}{30} \right)^2} - 1.09 \cdot \left(1 + \frac{150}{30} \right) \right] \\ &= 9668 \text{ N} \quad (c) \end{aligned}$$

$$\begin{aligned} F_{V,Rk,d} &= 1.05 \cdot \frac{f_{h,1,k} \cdot t_1 \cdot d}{2 + \beta} \cdot \left[\sqrt{2 \cdot \beta \cdot (1 + \beta) + \frac{4 \cdot \beta \cdot (2 + \beta) \cdot M_{y,Rk}}{f_{h,1,k} \cdot d \cdot t_1^2}} - \beta \right] \\ &= 1.05 \cdot \frac{18.6 \cdot 150 \cdot 8}{2 + 1.09} \cdot \left[\sqrt{2 \cdot 1.09 \cdot (1 + 1.09) + \frac{4 \cdot 1.09 \cdot (2 + 1.09) \cdot 20300}{18.6 \cdot 8 \cdot 150^2}} - 1.09 \right] \\ &= 8072 \text{ N} \quad (d) \end{aligned}$$

TIMBER-TO-TIMBER CONNECTION CALCULATION EXAMPLE

$$F_{V,Rk,e} = 1.05 \cdot \frac{f_{h,1,k} \cdot t_2 \cdot d}{1 + 2 \cdot \beta} \cdot \left[\sqrt{2 \cdot \beta^2 \cdot (1 + \beta) + \frac{4 \cdot \beta \cdot (1 + 2 \cdot \beta) \cdot M_{y,Rk}}{f_{h,1,k} \cdot d \cdot t_2^2}} - \beta \right]$$

$$= 1.05 \cdot \frac{18.6 \cdot 150 \cdot 8}{1 + 2 \cdot 1.09} \cdot \left[\sqrt{2 \cdot 1.09^2 \cdot (1 + 1.09) + \frac{4 \cdot 1.09 \cdot (1 + 2 \cdot 1.09) \cdot 20300}{18.6 \cdot 8 \cdot 150^2}} - 1.09 \right]$$

$$= 8539 \text{ N} \quad (\text{e})$$

$$F_{V,Rk,f} = 1.15 \cdot \sqrt{\frac{2 \cdot \beta}{1 + \beta}} \cdot \sqrt{2 \cdot M_{y,Rk} \cdot f_{h,1,k} \cdot d}$$

$$= 1.15 \cdot \sqrt{\frac{2 \cdot 1.09}{1 + 1.09}} \cdot \sqrt{2 \cdot 20300 \cdot 18.6 \cdot 8} = 2888 \text{ N} \quad (\text{f})$$

load bearing capacity of the rope effect:

$$\Delta F_{V,Rd} = \min \left\{ F_{V,Rd}; \frac{F_{ax,Rd}}{4} \right\}$$

$$F_{ax,Rd} = \min \left\{ \begin{array}{l} \text{withdrawal resistance in member 1} \\ \text{withdrawal resistance in member 2} \\ \text{screw tension resistance} \end{array} \right\}$$

determination of withdrawal resistance in element 1:

$$F_{ax,Rk,1} = f_{ax,k,90} \cdot k_{ax} \cdot k_{sys} \cdot \left(\frac{\rho_k}{\rho_{k,ref}} \right)^{k_p} \cdot d \cdot l_{ef,1}$$

$$f_{ax,k,90} \quad 13.1 \text{ N/mm}^3 \text{ (acc. to ETA-22/0789:2023, table A6.1)}$$

$$k_{ax} \quad 1.0 \text{ for } 30^\circ \leq \alpha \leq 90^\circ$$

$$k_{sys} \quad 1.13 \text{ for 5 penetrated layers (acc. to ETA-22/0789:2023, table A6.6)}$$

$$\rho_k \quad 350 \text{ kg/m}^3 \text{ characteristic density of the timber raw material}$$

$$\rho_{k,ref} \quad 350 \text{ kg/m}^3 \text{ reference characteristic density of the timber raw material}$$

$$k_p \quad 1.10 \text{ for softwood and } 15^\circ \leq \alpha \leq 90^\circ$$

$$l_{ef,1} \quad 140 \text{ mm}$$

$$F_{ax,Rk,1} = 13.1 \cdot 1.0 \cdot 1.13 \cdot \left(\frac{350}{350} \right)^{1.10} \cdot 8 \cdot 140 = 16579 \text{ N}$$

design value of the withdrawal resistance in element 2:

$$F_{ax,Rk,2} = f_{ax,k,90} \cdot k_{ax} \cdot k_{sys} \cdot \left(\frac{\rho_k}{\rho_{k,ref}} \right)^{k_p} \cdot d \cdot l_{ef,2}$$

$$f_{ax,k,90} \quad 13.1 \text{ N/mm}^3 \text{ (acc. to ETA-22/0789:2023, table A6.1)}$$

$$k_{ax} \quad 1.0 \text{ for } 30^\circ \leq \alpha \leq 90^\circ$$

$$k_{sys} \quad 1.12 \text{ for 4 penetrated layers (acc. to ETA-22/0789:2023, table A6.6)}$$

$$\rho_k \quad 350 \text{ kg/m}^3 \text{ characteristic density of the timber raw material}$$

FULLY THREADED SCREWS

B.1.2.1 mechanically jointed ribbed slab

$\rho_{k,ref}$ 350 kg/m³ reference characteristic density of the timber raw material

k_p 1.10 for softwood and $15^\circ \leq \alpha \leq 90^\circ$

$l_{ef,2}$ 150 mm

$$F_{ax,Rk,2} = 13.1 \cdot 1.0 \cdot 1.12 \cdot \left(\frac{350}{350}\right)^{1.10} \cdot 8 \cdot 150 = 17606 \text{ N}$$

screw tension resistance:

$F_{tens,k}$ 24100 N (acc. to ETA-22/0789:2023, table A6.1)

design value of the load bearing capacity of the single screw:

$$F_{ax,Rd} = \min \left\{ \begin{array}{l} F_{head,Rd,1} \\ F_{ax,Rd,2} \\ F_{tens,d} \end{array} \right\} = \min \left\{ \begin{array}{l} F_{head,Rk,1} \cdot k_{mod} / \gamma_M \\ F_{ax,Rk,2} \cdot k_{mod} / \gamma_M \\ F_{tens,k} / \gamma_{M2} \end{array} \right\}$$

k_{mod} 0.8 (SC1, duration of load medium-term)

γ_M 1.30 (for connections in timber construction acc. to EN 1995-1-1, table 2.3)

γ_{M2} 1.25 (for steel tension failure acc. to EN 1993-1-1:2014, section 6.1)

$$F_{ax,Rd} = \min \left\{ \begin{array}{l} 16579 \cdot 0.8 / 1.30 \\ 17606 \cdot 0.8 / 1.30 \\ 24100 / 1.25 \end{array} \right\} = \min \left\{ \begin{array}{l} 10203 \\ 10835 \\ 19280 \end{array} \right\} = 10203 \text{ N}$$

design value of the load bearing capacity of the rope effect:

$$\Delta F_{V,Rd,i} = \min \left\{ \begin{array}{l} F_{v,Rd,i} \\ 10203 / 4 \end{array} \right\} = \min \left\{ \begin{array}{l} F_{v,Rd,i} \\ 2551 \text{ N} \end{array} \right\}$$

design value of the load bearing capacity of the single shear timber-to-timber connection:

$$F_{V,Rd} = \min \left\{ \begin{array}{l} F_{V,Rk,a} \cdot k_{mod} / \gamma_M \quad (a) \\ F_{V,Rk,b} \cdot k_{mod} / \gamma_M \quad (b) \\ F_{V,Rk,c} \cdot k_{mod} / \gamma_M + \Delta F_{V,Rd} \quad (c) \\ F_{V,Rk,d} \cdot k_{mod} / \gamma_M + \Delta F_{V,Rd} \quad (d) \\ F_{V,Rk,e} \cdot k_{mod} / \gamma_M + \Delta F_{V,Rd} \quad (e) \\ F_{V,Rk,f} \cdot k_{mod} / \gamma_M + \Delta F_{V,Rd} \quad (f) \end{array} \right\} = \min \left\{ \begin{array}{l} 22332 \cdot 0.8 / 1.30 \quad (a) \\ 24362 \cdot 0.8 / 1.30 \quad (b) \\ 9668 \cdot 0.8 / 1.30 + 2551 \quad (c) \\ 8072 \cdot 0.8 / 1.30 + 2551 \quad (d) \\ 8539 \cdot 0.8 / 1.30 + 2551 \quad (e) \\ 2888 \cdot 0.8 / 1.30 + 1777 \quad (f) \end{array} \right\}$$

$$= \min \left\{ \begin{array}{l} 13743 \quad (a) \\ 14992 \quad (b) \\ 8500 \quad (c) \\ 7518 \quad (d) \\ 7806 \quad (e) \\ 3555 \quad (f) \end{array} \right\} = 3555 \text{ N}$$

verification

$$F_{Ed,1} \leq F_{V,Rd}$$

$$2574 \text{ N} \leq 3555 \text{ N}$$

verification fulfilled (72 %)

TIMBER-TO-TIMBER CONNECTION CALCULATION EXAMPLE

variant 2: $\alpha = 45^\circ$ to grain

The fully threaded screws inserted at an angle of $\alpha = 45^\circ$ are mainly loaded axially.

determination of the load bearing capacity of the flexible jointed beam

$(EI)_{\text{ef}}$ effective bending stiffness

$$(EI)_{\text{ef}} = \sum_{i=1}^2 (E_i \cdot I_i + \gamma_i \cdot E_i \cdot A_i \cdot a_i^2)$$

$$A_1 = b_1 \cdot h_1 = 1000 \cdot 150 = 150000 \text{ mm}^2$$

$$I_1 = \frac{b_1 \cdot h_1^3}{12} = \frac{1000 \cdot 150^3}{12} = 60750000 \text{ mm}^4$$

$$A_2 = b_2 \cdot h_2 = 200 \cdot 500 = 100000 \text{ mm}^2$$

$$I_2 = \frac{b_2 \cdot h_2^3}{12} = \frac{200 \cdot 500^3}{12} = 20.8 \cdot 10^8 \text{ mm}^4$$

$$\gamma_2 = 1$$

$$\gamma_1 = \frac{1}{1 + \pi^2 \cdot \frac{E_1 \cdot A_1 \cdot s_1}{K_1 \cdot I^2}}$$

For the determination of the stiffness K_1 of the at an angle inserted screws in a flexible jointed beam the share of the lateral and the share of the axial stiffness can be taken into account. The slip modulus per joint and per screw K_{ser} for the serviceability limit state is determined acc. to ETA-22/0789:2023, section A.7.1, with:

$K_{\text{ser,ax}}$ slip modulus for axially loaded screws in soft wood (acc. to ETA-22/0789:2023, section A.6.1.7)

$K_{\text{ser,v}}$ slip modulus for laterally loaded screws in soft wood (acc. to ETA-22/0789:2023, section A.6.2.4)

$$K_{\text{ser,ax}} = \frac{1}{1/K_{\text{ser,ax,lef1}} + 1/K_{\text{ser,ax,lef2}}} = \frac{k_{\text{HA}} \cdot d}{1/l_{\text{ef,1}} + 1/l_{\text{ef,2}}} = \frac{25 \cdot 8}{1/194 + 1/188} = 19095 \text{ N/mm}$$

$$K_{\text{ser,v}} = \rho_{\text{mean}}^{1.5} \cdot \frac{d}{23} = 385^{1.5} \cdot \frac{8}{23} = 2628 \text{ N/mm}$$

$$\begin{aligned} K_1 &= \frac{2}{3} \cdot K_{\text{ser}} = \frac{2}{3} \cdot [K_{\text{ser,v}} \cdot \sin \alpha \cdot (\sin \alpha - \mu \cdot \cos \alpha) + K_{\text{ser,ax}} \cdot \cos \alpha \cdot (\cos \alpha + \mu \cdot \sin \alpha)] = \\ &= \frac{2}{3} \cdot [2628 \cdot \sin 45 \cdot (\sin 45 - 0.3 \cdot \cos 45) + 19095 \cdot \cos 45 \cdot (\cos 45 + 0.3 \cdot \sin 5)] = \\ &= \frac{2}{3} \cdot [1065 + 12412] = \frac{2}{3} \cdot 13477 = 8985 \text{ N/mm} \end{aligned}$$

$$\gamma_1 = \frac{1}{1 + \pi^2 \cdot \frac{11600 \cdot 150000 \cdot 250}{8985 \cdot 6000^2}} = 0.0701$$

FULLY THREADED SCREWS

B.1.2.1 mechanically jointed ribbed slab

$$a_2 = \frac{\gamma_1 \cdot E_1 \cdot A_1 \cdot (h_1 + h_2)}{2 \cdot \sum_{i=1}^2 \gamma_i \cdot E_i \cdot A_i} =$$

$$= \frac{0.0701 \cdot 11600 \cdot 150000 \cdot (150 + 500)}{2 \cdot (0.0701 \cdot 11600 \cdot 150000 + 1 \cdot 11500 \cdot 100000)} = 31 \text{ mm}$$

$$a_1 = \frac{h_1 + h_2}{2} - a_2 = \frac{150 + 500}{2} - 31 = 294 \text{ mm}$$

$$(EI)_{ef} = 11600 \cdot 60750000 + 0.0701 \cdot 11600 \cdot 150000 \cdot 294^2 +$$

$$+ 11500 \cdot 20.8 \cdot 10^8 + 1 \cdot 11500 \cdot 100000 \cdot 31^2 = 3.63 \cdot 10^{13} \text{ Nmm}^2$$

action design value of the single screw

$$F_{Ed,1} = \frac{\gamma_1 \cdot E_1 \cdot A_1 \cdot a_1 \cdot s_1}{(EI)_{ef}} \cdot V_{Ed} =$$

$$= \frac{0.0701 \cdot 11600 \cdot 150000 \cdot 294 \cdot 250}{3.63 \cdot 10^{13}} \cdot 35000 = 8643 \text{ N}$$

determination of the load bearing capacity of the single screw

determination of withdrawal resistance in element 1:

$$F_{ax,45,Rk,1} = f_{ax,k,90} \cdot k_{ax} \cdot k_{sys} \cdot \left(\frac{\rho_k}{\rho_{k,ref}} \right)^{k_p} \cdot d \cdot l_{ef,1}$$

$f_{ax,k,90}$ 13.1 N/mm³ (acc. to ETA-22/0789:2023, table A6.1)

k_{ax} 1.0 for 30° ≤ α ≤ 90°

k_{sys} 1.13 for 5 penetrated layers (acc. to ETA-22/0789:2023, table A6.6)

ρ_k 350 kg/m³ characteristic density of the timber raw material

$\rho_{k,ref}$ 350 kg/m³ reference characteristic density of the timber raw material

k_p 1.10 for softwood and 15° ≤ α ≤ 90°

$l_{ef,1}$ 194 mm

$$F_{ax,45,Rk,1} = 13.1 \cdot 1.0 \cdot 1.13 \cdot \left(\frac{350}{350} \right)^{1.10} \cdot 8 \cdot 194 = 22974 \text{ N}$$

determination of withdrawal resistance in element 2:

$$F_{ax,45,Rk,2} = f_{ax,k,90} \cdot k_{ax} \cdot k_{sys} \cdot \left(\frac{\rho_k}{\rho_{k,ref}} \right)^{k_p} \cdot d \cdot l_{ef,2}$$

$f_{ax,k,90}$ 13.1 N/mm³ (acc. to ETA-22/0789:2023, table A6.1)

k_{ax} 1.0 for 30° ≤ α ≤ 90°

k_{sys} 1.13 for 5 penetrated layers (acc. to ETA-22/0789:2023, table A6.6)

ρ_k 350 kg/m³ characteristic density of the timber raw material

TIMBER-TO-TIMBER CONNECTION CALCULATION EXAMPLE

$\rho_{k,ref}$ 350 kg/m³ reference characteristic density of the timber raw material

k_ρ 1.10 for softwood and $15^\circ \leq \alpha \leq 90^\circ$

$l_{ef,2}$ 196 mm

$$F_{ax,45,Rk,2} = 13.1 \cdot 1.0 \cdot 1.06 \cdot \left(\frac{350}{350}\right)^{1.10} \cdot 8 \cdot 196 = 21773 \text{ N}$$

screw tension resistance:

$F_{tens,k}$ 24100 N (acc. to ETA- 22/0789:2023, table A6.1)

Design value of the axial load-bearing capacity of the screw:

$$F_{ax,45,Rd} = \min \left\{ \begin{array}{l} F_{head,Rd,1} \\ F_{ax,Rd,2} \\ F_{tens,d} \end{array} \right\} = \min \left\{ \begin{array}{l} F_{head,Rk,1} \cdot k_{mod} / \gamma_M \\ F_{ax,Rk,2} \cdot k_{mod} / \gamma_M \\ F_{tens,k} / \gamma_{M2} \end{array} \right\}$$

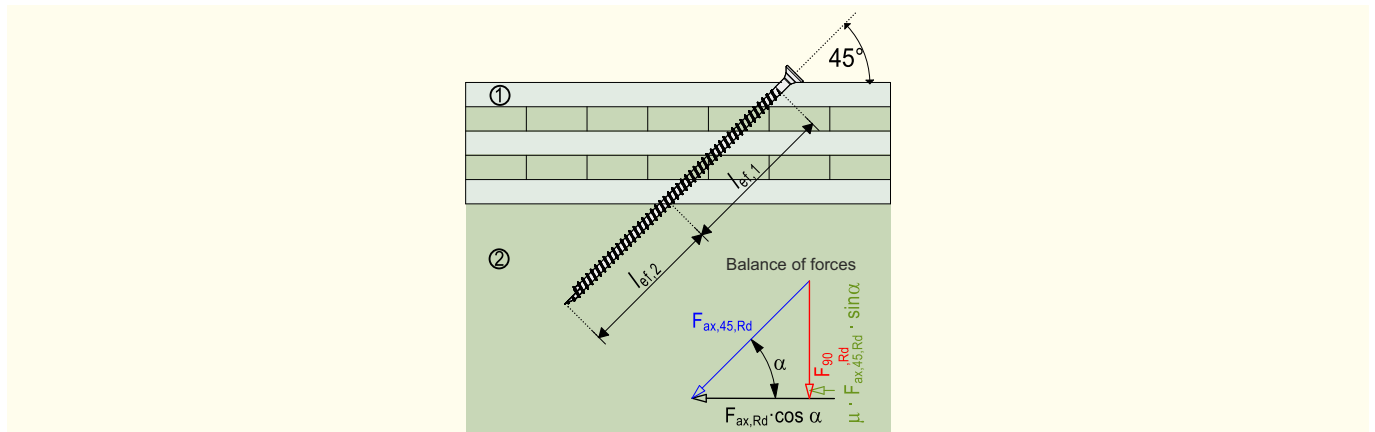
k_{mod} 0.8 (NKL 1, C24, medium load duration)

γ_M 1.30 (for connections in timber construction acc. to EN 1995-1-1, table 2.3)

γ_{M2} 1.25 (for steel tension failure acc. to EN 1993-1-1:2014, section 6.1)

$$F_{ax,45,Rd} = \min \left\{ \begin{array}{l} 22974 \cdot 0.8 / 1.30 \\ 21773 \cdot 0.8 / 1.30 \\ 24100 / 1.25 \end{array} \right\} = \min \left\{ \begin{array}{l} 14138 \\ 13399 \\ 19280 \end{array} \right\} = 13399 \text{ N}$$

determination of the horizontal resistance:



$$F_{Rd} = F_{ax,45,Rd} \cdot (\cos \alpha + \mu \cdot \sin \alpha) = 13399 \cdot (\cos 45 + 0.3 \cdot \sin 45) = 12317 \text{ N}$$

μ 0.3 friction coefficient between the timber members (acc. to ETA- 22/0789:2023, section A.7.1)

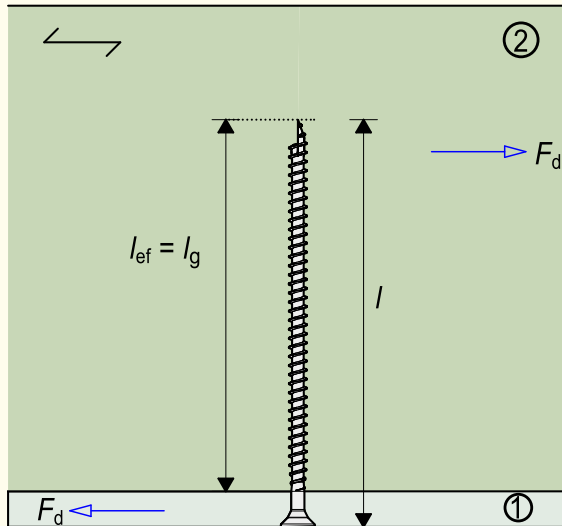
verification screw

$$F_{Ed} \leq F_{Rd}$$

$$8643 \text{ N} \leq 12317 \text{ N}$$

verification fulfilled (70 %)

FULLY THREADED SCREWS

B.2.1.1 general - connection between timber element and thick steel plate ($\alpha = 90^\circ$, $\varepsilon = 0^\circ$)

DETAILS

service class SC1

loading

$$F_{Ed} = 2000 \text{ N}$$

(duration of load medium-term)

construction elements

construction element 1:

steel plate $t = 10\text{mm}$

construction element 2:

solid timber, C24

Wood Screw C-FT-8x180/170

$$d = 8 \text{ mm}, l = 180 \text{ mm}, l_g = l_{ef} = 170 \text{ mm}$$

determination of embedment strength and yield moment

(acc. to ETA-22/0789:2023, section A.6.2.3)

 α 90° , axis-grain-angle ε 0° , load-grain-angle

$$f_{h,k} = k_\alpha \cdot k_\beta \cdot k_\varepsilon \cdot f_{h,k,ref}$$

$$k_\alpha = \frac{1}{2.5 \cdot \cos^2(\alpha) + \sin^2(\alpha)} = \frac{1}{2.5 \cdot \cos^2(90) + \sin^2(90)} = 1.0$$

$$k_\beta = 1.0$$

$$k_\varepsilon = k_{90} \cdot \cos^2(\varepsilon) + \sin^2(\varepsilon) = 1.2 \cdot \cos^2(0) + \sin^2(0) = 1.20$$

 k_{90} 1.20 in the member of the point side ρ_k 350 kg/m³ characteristic density of the timber element $f_{h,k,ref}$ characteristic reference embedment strength of non-predrilled timber elements

$$f_{h,k,ref} = 0.082 \cdot \rho_k \cdot d^{-0.3} = 0.082 \cdot 350 \cdot 8^{-0.3} = 15.4 \text{ N/mm}^2$$

$$f_{h,k} = 1.0 \cdot 1.0 \cdot 1.2 \cdot 15.4 = 18.5 \text{ N/mm}^2$$

 $M_{\gamma,Rk}$ 20.3 Nm $\hat{=}$ 20300 Nmm, characteristic yield moment (acc. to ETA- 22/0789:2023, table A6.1)



determination of the load bearing capacity of the single shear steel-to-timber connection with a thick steel plate

(acc. to EN 1995-1-1, section 8.2.3 with equation 8.10)

The verification is made for a thick steel plate due to the greater thickness t than the screw diameter d .

$$F_{V,Rd} = \min \left\{ \begin{array}{l} F_{V,Rd,c} \quad (c) \\ F_{V,Rd,d} + \Delta F_{V,Rd} \quad (d) \\ F_{V,Rd,e} + \Delta F_{V,Rd} \quad (e) \end{array} \right\}$$

$$F_{V,Rk,c} = f_{h,k} \cdot t_1 \cdot d = 18.5 \cdot 170 \cdot 8 = 25100 \text{ N} \quad (c)$$

$$F_{V,Rk} = f_{h,k} \cdot t_1 \cdot d \cdot \left[\sqrt{2 + \frac{4 \cdot M_{y,Rk}}{f_{h,k} \cdot d \cdot t_1^2}} - 1 \right]$$

$$= 18.5 \cdot 170 \cdot 8 \cdot \left[\sqrt{2 + \frac{4 \cdot 20300}{18.5 \cdot 8 \cdot 170^2}} - 1 \right] = 10565 \text{ N} \quad (d)$$

$$F_{V,Rk,e} = 2.3 \cdot \sqrt{M_{y,Rk} \cdot f_{h,k} \cdot d}$$

$$= 2.3 \cdot \sqrt{20300 \cdot 18.5 \cdot 8} = 3982 \text{ N} \quad (e)$$

load bearing capacity of the rope effect:

$$\Delta F_{V,Rd,i} = \min \left\{ F_{V,Rd,i}, \frac{F_{ax,Rd}}{4} \right\}$$

$$F_{ax,Rd} = \min \left\{ \begin{array}{l} \text{withdrawal resistance} \\ \text{screw tension resistance} \end{array} \right\}$$

determination of withdrawal resistance:

$$F_{ax,Rk} = f_{ax,k,90} \cdot k_{ax} \cdot k_{sys} \cdot \left(\frac{\rho_k}{\rho_{k,ref}} \right)^{k_p} \cdot d \cdot l_{ef}$$

$$f_{ax,k,90} \quad 13.1 \text{ N/mm}^3 \text{ (acc. to ETA-22/0789:2023, table A6.1)}$$

$$k_{ax} \quad 1.0 \text{ for } 30^\circ \leq \alpha \leq 90^\circ$$

$$k_{sys} \quad 1.00 \text{ for solid timber}$$

$$\rho_k \quad 350 \text{ kg/m}^3 \text{ characteristic density of the timber raw material}$$

$$\rho_{k,ref} \quad 350 \text{ kg/m}^3 \text{ reference characteristic density of the timber raw material}$$

$$k_p \quad 1.10 \text{ for softwood and } 15^\circ \leq \alpha \leq 90^\circ$$

$$l_{ef} \quad 170 \text{ mm}$$

$$F_{ax,Rk} = 13.1 \cdot 1.0 \cdot 1.00 \cdot \left(\frac{350}{350} \right)^{1.10} \cdot 8 \cdot 170 = 17816 \text{ N}$$

FULLY THREADED SCREWS

B.2.1.1 general - connection between timber element and thick steel plate ($\alpha = 90^\circ$, $\varepsilon = 0^\circ$)

determination of screw tension resistance:

$$F_{\text{tens},k} = 24100 \text{ N (acc. to ETA-22/0789:2023, table A6.1)}$$

design value of the load bearing capacity of the single screw:

$$F_{\text{ax},\text{Rd}} = \min \left\{ \begin{array}{l} F_{\text{ax},\text{Rk}} \cdot k_{\text{mod}} / \gamma_{\text{M}} \\ F_{\text{tens},k} / \gamma_{\text{M2}} \end{array} \right\}$$

$$k_{\text{mod}} = 0.8 \text{ (SC1, duration of load medium-term)}$$

$$\gamma_{\text{M}} = 1.30 \text{ (for connections in timber construction acc. to EN 1995-1-1, table 2.3)}$$

$$\gamma_{\text{M2}} = 1.25 \text{ (for steel tension failure acc. to EN 1993-1-1:2014, section 6.1)}$$

$$F_{\text{ax},\text{Rd}} = \min \left\{ \begin{array}{l} 17816 \cdot 0.8 / 1.30 \\ 24100 / 1.25 \end{array} \right\} = \min \left\{ \begin{array}{l} 10964 \\ 19280 \end{array} \right\} = 10964 \text{ N}$$

design value of the load bearing capacity of the rope effect:

$$\Delta F_{\text{V},\text{Rd}} = \min \left\{ \begin{array}{l} F_{\text{V},\text{Rd}} \\ 10964 / 4 \end{array} \right\} = \min \left\{ \begin{array}{l} F_{\text{V},\text{Rd}} \\ 2741 \text{ N} \end{array} \right\}$$

design value of the load bearing capacity of the single shear timber-to-steel connection with a thick steel plate:

$$F_{\text{V},\text{Rd}} = \min \left\{ \begin{array}{l} F_{\text{V},\text{Rk},\text{c}} \cdot k_{\text{mod}} / \gamma_{\text{M}} \quad (\text{c}) \\ F_{\text{V},\text{Rk},\text{d}} \cdot k_{\text{mod}} / \gamma_{\text{M}} + \Delta F_{\text{V},\text{Rd}} \quad (\text{d}) \\ F_{\text{V},\text{Rk},\text{e}} \cdot k_{\text{mod}} / \gamma_{\text{M}} + \Delta F_{\text{V},\text{Rd}} \quad (\text{e}) \end{array} \right\} = \min \left\{ \begin{array}{l} 25100 \cdot 0.8 / 1.30 \quad (\text{c}) \\ 10565 \cdot 0.8 / 1.30 + 2741 \quad (\text{d}) \\ 3982 \cdot 0.8 / 1.30 + 2450 \quad (\text{e}) \end{array} \right\}$$

$$= \min \left\{ \begin{array}{l} 15446 \quad (\text{c}) \\ 9243 \quad (\text{d}) \\ 4901 \quad (\text{e}) \end{array} \right\} = 4901 \text{ N}$$

verification

The load-bearing capacity must be reduced by 50 % as only one screw is applied in the connection (see ETA-22/0789:2023, section 2.2)

$$F_{\text{Ed}} \leq \frac{F_{\text{V},\text{Rd}}}{2}$$

$$2000 \text{ N} \leq \frac{4901 \text{ N}}{2}$$

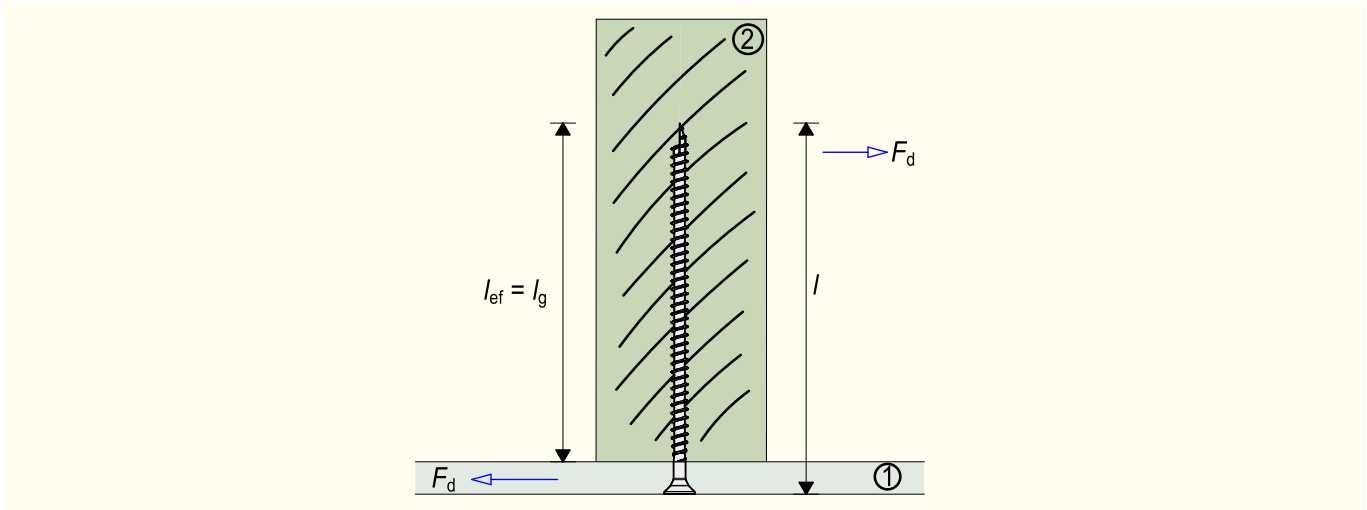
$$2000 \text{ N} \leq 2450 \text{ N}$$

verification fulfilled (82 %)

STEEL-TO-TIMBER CONNECTION CALCULATION EXAMPLE



load bearing capacity at an load-grain-angle of $\varepsilon = 90^\circ$ ($\alpha = 0^\circ$)



$\varepsilon = 90^\circ$, load-grain angle

due to the different load-grain angle ε the factor k_ε and the embedment strength changes:

$$k_\varepsilon = k_{90} \cdot \cos^2(\varepsilon) + \sin^2(\varepsilon) = 1.2 \cdot \cos^2(90) + \sin^2(90) = 1.00$$

$$f_{h,k} = 1.0 \cdot 1.0 \cdot 1.00 \cdot 15.4 = 15.4 \text{ N/mm}^2$$

load bearing capacity of the rope effect:

$$\Delta F_{V,Rd} = \min \left\{ \frac{F_{V,Rd,i}}{10964 / 4} \right\} = \min \left\{ \frac{F_{V,Rd,i}}{2741 \text{ N}} \right\}$$

design value of the load bearing capacity of the single shear timber-to-steel connection with a thick steel plate:

$$F_{V,Rd} = \min \left\{ \begin{array}{l} F_{V,Rk,c} \cdot k_{mod} / \gamma_M \quad (c) \\ F_{V,Rk,d} \cdot k_{mod} / \gamma_M + \Delta F_{V,Rd} \quad (d) \\ F_{V,Rk,e} \cdot k_{mod} / \gamma_M + \Delta F_{V,Rd} \quad (e) \end{array} \right\} = \min \left\{ \begin{array}{l} 20917 \cdot 0.8 / 1.30 \quad (c) \\ 8832 \cdot 0.8 / 1.30 + 2741 \quad (d) \\ 3635 \cdot 0.8 / 1.30 + 2237 \quad (e) \end{array} \right\}$$

$$= \min \left\{ \begin{array}{l} 12872 \quad (c) \\ 8176 \quad (d) \\ 4474 \quad (e) \end{array} \right\} = 4474 \text{ N}$$

verification

The load-bearing capacity must be reduced by 50 % as only one screw is applied in the connection (see ETA-22/0789:2023, section 2.2)

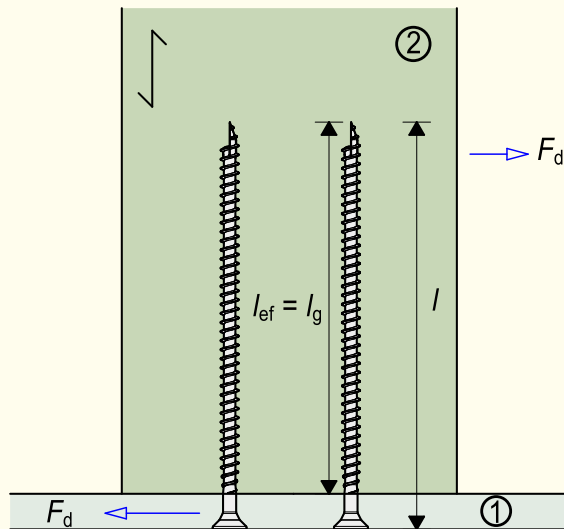
$$F_{Ed} \leq \frac{F_{V,Rd}}{2}$$

$$2000 \text{ N} \leq \frac{4474 \text{ N}}{2}$$

$$2000 \text{ N} \leq 2237 \text{ N}$$

verification fulfilled (89 %)

FULLY THREADED SCREWS

B.2.1.2 general - connection between timber element and thick steel plate ($\alpha = 0^\circ$, $\varepsilon = 90^\circ$)

DETAILS

service class SC1

loading

$$F_{E,d} = 6000 \text{ N}$$

(duration of load medium-term)

construction elements

construction element 1:

steelplate, $t = 10\text{mm}$

construction element 2:

solid timber, C24

Wood Screw C-FT-8x180/170

$$d = 8 \text{ mm}, l = 180 \text{ mm}, l_g = l_{ef} = 170 \text{ mm}$$

4 screws

minimum spacing and minimum penetration length

(acc. to ETA-22/0789:2023, table A6.4)

$$a_2 = 40 \text{ mm} \geq 5 \cdot d = 5 \cdot 8 = 40 \text{ mm} \rightarrow \text{OK}$$

$$a_{4,c} = 40 \text{ mm} \geq 2,5 \cdot d = 2,5 \cdot 8 = 20 \text{ mm} \rightarrow \text{OK}$$

$$a_{4,t} = 40 \text{ mm} \geq 5 \cdot d = 5 \cdot 8 = 40 \text{ mm} \rightarrow \text{OK}$$

minimum penetration length of the screw at an angle of $\leq 15^\circ$ between the screw axis and the grain direction (acc. to ETA-22/0789:2023, section 2.2)

$$l - t = 180 - 10 = 170 \text{ mm} \geq 20 \cdot d = 20 \cdot 8 = 160 \text{ mm} \rightarrow \text{OK}$$

determination of embedment strength and yield moment

(acc. to ETA-22/0789:2023, section A.6.2.3)

 α 0° , axis-grain-angle ε 90° , load-grain-angle

$$f_{h,k} = k_\alpha \cdot k_\beta \cdot k_\varepsilon \cdot f_{h,k,ref}$$

$$k_\alpha = \frac{1}{2,5 \cdot \cos^2(\alpha) + \sin^2(\alpha)} = \frac{1}{2,5 \cdot \cos^2(0) + \sin^2(0)} = 0,4$$

$$k_\beta = 1,0$$

$$k_\varepsilon = k_{90} \cdot \cos^2(\varepsilon) + \sin^2(\varepsilon) = 1,2 \cdot \cos^2(90) + \sin^2(90) = 1,00$$

STEEL-TO-TIMBER CONNECTION CALCULATION EXAMPLE



k_{90} 1.20 in the member of the point side

ρ_k 350 kg/m³ characteristic density of the timber element

$f_{h,k,ref}$ characteristic reference embedment strength of non-predrilled timber elements

$$f_{h,k,ref} = 0.082 \cdot \rho_k \cdot d^{-0.3} = 0.082 \cdot 350 \cdot 8^{-0.3} = 15.4 \text{ N/mm}^2$$

$$f_{h,k} = 0.4 \cdot 1.0 \cdot 1.00 \cdot 15.4 = 6.2 \text{ N/mm}^2$$

$M_{y,Rk}$ 20.3 Nm $\hat{=}$ 20300 Nmm, characteristic yield moment (acc. to ETA-22/0789:2023, table A6.1)

determination of the load bearing capacity of the single shear steel-to-timber connection with a thick steel plate

(acc. to EN 1995-1-1, section 8.2.3 with equation 8.10)

The verification is made for a thick steelplate due to the greater thickness t than the screw diameter d .

$$F_{V,Rd} = \min \left\{ \begin{array}{l} F_{V,Rd,c} \quad (c) \\ F_{V,Rd,d} + \Delta F_{V,Rd} \quad (d) \\ F_{V,Rd,e} + \Delta F_{V,Rd} \quad (e) \end{array} \right\}$$

$$F_{V,Rk,c} = f_{h,k} \cdot t_1 \cdot d = 6.2 \cdot 170 \cdot 8 = 8367 \text{ N} \quad (c)$$

$$F_{V,Rk} = f_{h,k} \cdot t_1 \cdot d \cdot \left[\sqrt{2 + \frac{4 \cdot M_{y,Rk}}{f_{h,k} \cdot d \cdot t_1^2}} - 1 \right]$$

$$= 6.2 \cdot 170 \cdot 8 \cdot \left[\sqrt{2 + \frac{4 \cdot 20300}{6.2 \cdot 8 \cdot 170^2}} - 1 \right] = 3633 \text{ N} \quad (d)$$

$$F_{V,Rk,e} = 2.3 \cdot \sqrt{M_{y,Rk} \cdot f_{h,k} \cdot d}$$

$$= 2.3 \cdot \sqrt{20300 \cdot 6.2 \cdot 8} = 2299 \text{ N} \quad (e)$$

load bearing capacity of the rope effect:

$$\Delta F_{V,Rd} = \min \left\{ F_{V,Rd}, \frac{F_{ax,Rd}}{4} \right\}$$

$$F_{ax,Rd} = \min \left\{ \begin{array}{l} \text{withdrawal resistance} \\ \text{screw tension resistance} \end{array} \right\}$$

determination of withdrawal resistance:

$$F_{ax,Rk} = f_{ax,k,90} \cdot k_{ax} \cdot k_{sys} \cdot \left(\frac{\rho_k}{\rho_{k,ref}} \right)^{k_p} \cdot d \cdot l_{ef}$$

$f_{ax,k,90}$ 13.1 N/mm³ (acc. to ETA-22/0789:2023, table A6.1)

FULLY THREADED SCREWS

B.2.1.2 general - connection between timber element and thick steel plate ($\alpha = 0^\circ$, $\varepsilon = 90^\circ$)

$$k_{ax} = 0.3 \cdot k_{gap} + \frac{\alpha}{30^\circ} \cdot (1 - 0.3 \cdot k_{gap})$$

$$k_{gap} = 1.0$$

$$k_{ax} = 0.3 \cdot 1.0 + \frac{\alpha}{30} \cdot (1 - 0.3 \cdot 1.0) = 0.3$$

$$k_{sys} = 1.00 \text{ for solid timber}$$

$$\rho_k = 350 \text{ kg/m}^3 \text{ characteristic density of the timber raw material}$$

$$\rho_{k,ref} = 350 \text{ kg/m}^3 \text{ reference characteristic density of the timber raw material}$$

$$k_p = \text{for softwood and } 0^\circ \leq \alpha \leq 15^\circ:$$

$$k_p = 1.25 \cdot 0.05 \cdot d = 1.25 \cdot 0.05 \cdot 8 = 0.85$$

$$l_{ef} = 170 \text{ mm}$$

$$F_{ax,Rk} = 13.1 \cdot 0.3 \cdot 1.0 \cdot \left(\frac{350}{350}\right)^{0.85} \cdot 8 \cdot 170 = 5345 \text{ N}$$

determination of screw tension resistance:

$$F_{tens,k} = 24.1 \text{ kN} \equiv 24100 \text{ N (acc. to ETA-22/0789:2023, table A6.1)}$$

design value of the load bearing capacity of the single screw:

$$F_{ax,Rd} = \min \left\{ \frac{F_{ax,Rk} \cdot k_{mod}}{\gamma_M}, \frac{F_{tens,k}}{\gamma_{M2}} \right\}$$

$$k_{mod} = 0.8 \text{ (SC1, duration of load medium-term)}$$

$$\gamma_M = 1.30 \text{ (for connections in timber construction acc. to EN 1995-1-1, table 2.3)}$$

$$\gamma_{M2} = 1.25 \text{ (for steel tension failure acc. to EN 1993-1-1:2014, section 6.1)}$$

$$F_{ax,Rd} = \min \left\{ \frac{5345 \cdot 0.8}{1.30}, \frac{24100}{1.25} \right\} = \min \left\{ 3289, 19280 \right\} = 3289 \text{ N}$$

design value of the load bearing capacity of the rope effect:

$$\Delta F_{v,Rd} = \min \left\{ \frac{F_{v,Rd}}{4} \right\} = \min \left\{ \frac{F_{v,Rd}}{822 \text{ N}} \right\}$$

STEEL-TO-TIMBER CONNECTION CALCULATION EXAMPLE



design value of the load bearing capacity of the single shear timber to steel connection with a thick steel plate:

$$F_{V,Rd,n=1} = \min \left\{ \begin{array}{l} F_{V,Rk,c} \cdot k_{mod} / \gamma_M \quad (c) \\ F_{V,Rk,d} \cdot k_{mod} / \gamma_M + \Delta F_{V,Rd} \quad (d) \\ F_{V,Rk,e} \cdot k_{mod} / \gamma_M + \Delta F_{V,Rd} \quad (e) \end{array} \right\} = \min \left\{ \begin{array}{l} 8367 \cdot 0.8 / 1.30 \quad (c) \\ 3633 \cdot 0.8 / 1.30 + 822 \quad (d) \\ 2299 \cdot 0.8 / 1.30 + 822 \quad (e) \end{array} \right\}$$

$$= \min \left\{ \begin{array}{l} 5149 \quad (c) \\ 3058 \quad (d) \\ 2237 \quad (e) \end{array} \right\} = 2237 \text{ N}$$

a_1 is assumed as a_2

$$n_{ef} = n_{90} \cdot \min \left\{ n^{0.9} \cdot \sqrt[4]{\frac{a_1}{13 \cdot d}} \right\} = 2 \cdot \min \left\{ 2^{0.9} \cdot \sqrt[4]{\frac{40}{13 \cdot 8}} \right\} = 2.94$$

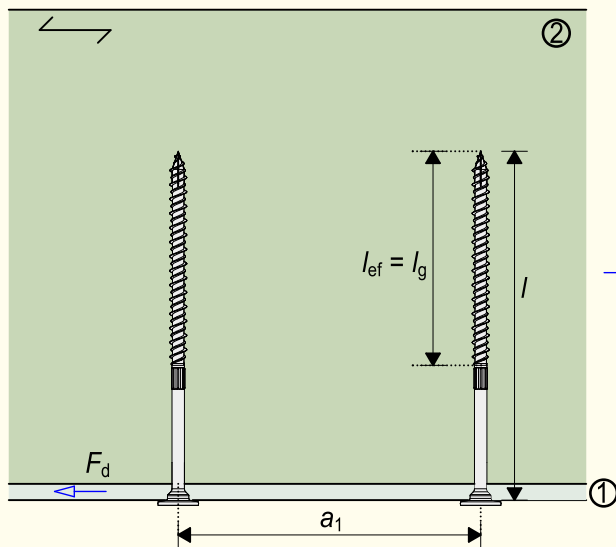
verification

$$F_{Ed} \leq n_{ef} \cdot F_{V,Rd,n=1}$$

$$6000 \text{ N} \leq 2.94 \cdot 2237 = 6575 \text{ N}$$

verification fulfilled (91 %)

FULLY THREADED SCREWS

B.2.2.1 general - connection between timber element and thin steel plate ($\alpha = 90^\circ$, $\varepsilon = 0^\circ$)

DETAILS

service class SC1

loading

$$F_{Ed} = 2000 \text{ N}$$

(duration of load medium-term)

construction elements

construction element 1:

steel plate $t = 4 \text{ mm}$

construction element 2:

solid timber, C24

Wood Screw W-LF-8x100/60

$$d = 8 \text{ mm}, l = 100 \text{ mm}, l_g = l_{ef} = 60 \text{ mm}$$

2 screws

minimum spacing

According to ETA-22/0789:2023, table A6.12 for laterally loaded screws without drill tip, the spacing of nails without pre-drilled holes can be applied (see EN 1995-1-1, table 8.2). For steel-to-timber connections the minimum spacings can be multiplied by a factor of 0.7 according to EN 1995-1-1, section 8.3.1.4 (1).

$\alpha = 0^\circ$ (load-grain angle for determination of minimum spacing acc. to EN 1995-1-1)

$$a_1 = 100 \text{ mm} \geq 0.7 \cdot (5+7 \cdot |\cos \alpha|) \cdot d = 0.7 \cdot (5+7 \cdot |\cos 0|) \cdot 8 = 67 \text{ mm} \rightarrow \text{OK}$$

determination of embedment strength and yield moment

(acc. to ETA-22/0789:2023, section A.6.2.3)

 $\alpha = 90^\circ$, axis-grain angle $\varepsilon = 0^\circ$, load-grain angle

$$f_{h,k} = k_\alpha \cdot k_\beta \cdot k_\varepsilon \cdot f_{h,k,ref}$$

$$k_\alpha = \frac{1}{2.5 \cdot \cos^2(\alpha) + \sin^2(\alpha)} = \frac{1}{2.5 \cdot \cos^2(90) + \sin^2(90)} = 1.0$$

$$k_\beta = 1.0$$

$$k_\varepsilon = k_{90} \cdot \cos^2(\varepsilon) + \sin^2(\varepsilon) = 1.2 \cdot \cos^2(0) + \sin^2(0) = 1.20$$

 $k_{90} = 1.20$ in the member of the point side $\rho_k = 350 \text{ kg/m}^3$ characteristic density of the timber element $f_{h,k,ref}$ characteristic reference embedment strength of non-predrilled timber elements

$$f_{h,k,ref} = 0.082 \cdot \rho_k \cdot d^{-0.3} = 0.082 \cdot 350 \cdot 8^{-0.3} = 15.4 \text{ N/mm}^2$$

$$f_{h,k} = 1.0 \cdot 1.0 \cdot 1.2 \cdot 15.4 = 18.5 \text{ N/mm}^2$$

 $M_{\gamma,Rk} = 22.6 \text{ Nm} \equiv 22600 \text{ Nmm}$, characteristic yield moment (acc. to ETA-22/0789:2023, table A6.2)determination of the load bearing capacity of the single shear steel-to-timber connection with a thin steel plate

(acc. to EN 1995-1-1, section 8.2.3 with equation 8.9) The verification is done for a thin steel plate due to the smaller or equal thickness t than the half screw diameter d .

$$F_{V,Rd} = \min \left\{ \begin{array}{l} F_{V,Rd,a} \quad (a) \\ F_{V,Rd,b} + \Delta F_{V,Rd} \quad (b) \end{array} \right\}$$

STEEL-TO-TIMBER CONNECTION CALCULATION EXAMPLE



$$F_{V,Rk,a} = 0.4 \cdot f_{h,k} \cdot t_1 \cdot d = 18.5 \cdot (100 - 4) \cdot 8 = 5670 \text{ N} \quad (\text{a})$$

$$F_{V,Rk,b} = 1.15 \cdot \sqrt{2 \cdot M_{y,Rk} \cdot f_{h,k} \cdot d}$$

$$= 1.15 \cdot \sqrt{2 \cdot 22600 \cdot 18.5 \cdot 8} = 2971 \text{ N} \quad (\text{b})$$

load bearing capacity of the rope effect:

$$\Delta F_{V,Rd} = \min \left\{ F_{V,Rd,i}; \frac{F_{ax,Rd}}{4} \right\}$$

$$F_{ax,Rd} = \min \left\{ \begin{array}{l} \text{withdrawal resistance} \\ \text{screw tension resistance} \end{array} \right\}$$

determination of withdrawal resistance:

$$F_{ax,Rk} = f_{ax,k,90} \cdot k_{ax} \cdot k_{sys} \cdot \left(\frac{\rho_k}{\rho_{k,ref}} \right)^{k_p} \cdot d \cdot l_{ef}$$

$$f_{ax,k,90} \quad 10.9 \text{ N/mm}^3 \text{ (acc. to ETA-22/0789:2023, table A6.2)}$$

$$k_{ax} \quad 1.0 \text{ for } 30^\circ \leq \alpha \leq 90^\circ$$

$$k_{sys} \quad 1.00 \text{ for solid timber}$$

$$\rho_k \quad 350 \text{ kg/m}^3 \text{ characteristic density of the timber raw material}$$

$$\rho_{k,ref} \quad 350 \text{ kg/m}^3 \text{ reference characteristic density of the timber raw material}$$

$$k_p \quad 1.10 \text{ for softwood and } 15^\circ \leq \alpha \leq 90^\circ$$

$$l_{ef} \quad 60 \text{ mm}$$

$$F_{ax,Rk} = 10.9 \cdot 1.0 \cdot 1.00 \cdot \left(\frac{350}{350} \right)^{1.10} \cdot 8 \cdot 60 = 5232 \text{ N}$$

determination of screw tension resistance:

$$F_{tens,k} \quad 23.3 \text{ kN} \equiv 23300 \text{ N} \text{ (acc. to ETA-22/0789:2023, table A6.2)}$$

design value of the load bearing capacity of the single screw:

$$F_{ax,Rd} = \min \left\{ \begin{array}{l} F_{ax,Rk} \cdot k_{mod} / \gamma_M \\ F_{tens,k} / \gamma_{M2} \end{array} \right\}$$

$$k_{mod} \quad 0.8 \text{ (SC1, duration of load medium-term)}$$

$$\gamma_M \quad 1.30 \text{ (for connections in timber construction acc. to EN 1995-1-1, table 2.3)}$$

$$\gamma_{M2} \quad 1.25 \text{ (for steel tension failure acc. to EN 1993-1-1:2014, section 6.1)}$$

$$F_{ax,Rd} = \min \left\{ \begin{array}{l} 5232 \cdot 0.8 / 1.30 \\ 23300 / 1.25 \end{array} \right\} = \min \left\{ \begin{array}{l} 3220 \\ 18640 \end{array} \right\} = 3220 \text{ N}$$

design value of the load bearing capacity of the rope effect:

$$\Delta F_{V,Rd,i} = \min \left\{ \begin{array}{l} F_{V,Rd,i} \\ 3220 / 4 \end{array} \right\} = \min \left\{ \begin{array}{l} F_{V,Rd,i} \\ 805 \text{ N} \end{array} \right\}$$

design value of the load bearing capacity of the single shear timber-to-steel connection with a thin steel plate:

$$F_{V,Rd} = \min \left\{ \begin{array}{l} F_{V,Rk,a} \cdot k_{mod} / \gamma_M \quad (\text{a}) \\ F_{V,Rk,b} \cdot k_{mod} / \gamma_M + \Delta F_{V,Rd} \quad (\text{b}) \end{array} \right\} = \min \left\{ \begin{array}{l} 5670 \cdot 0.8 / 1.30 \quad (\text{a}) \\ 2971 \cdot 0.8 / 1.30 + 805 \quad (\text{b}) \end{array} \right\}$$

$$= \min \left\{ \begin{array}{l} 3489 \quad (\text{a}) \\ 2633 \quad (\text{b}) \end{array} \right\} = 2633 \text{ N}$$

$$n_{ef} = n^{0.9} = 2^{0.9} = 1.87$$

verification

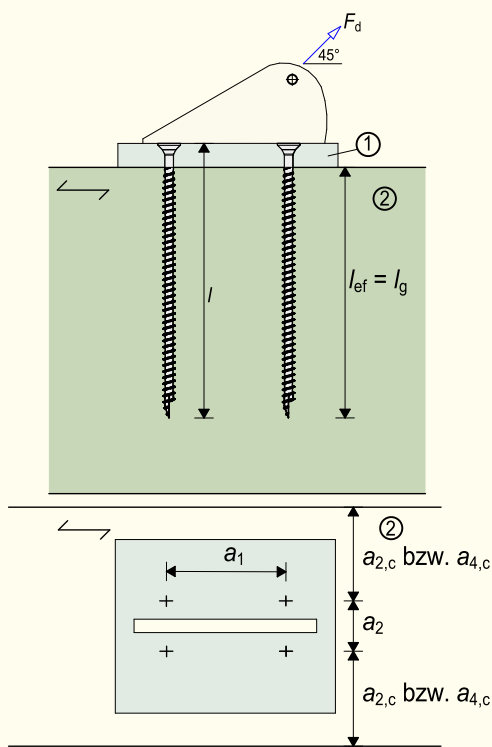
$$F_{Ed} \leq n_{ef} \cdot F_{V,Rd}$$

$$2000 \text{ N} \leq 1.87 \cdot 2633 = 4914 \text{ N}$$

verification fulfilled (41 %)

FULLY THREADED SCREWS

C.1 wind bracing connection



DETAILS

service class SC1

loading

$$F_{Ed} = 15000 \text{ N}$$

(duration of load short-term)

construction elements

construction element 1:

steel plate, $t = 15 \text{ mm}$

construction element 2:

solid timber, C24

Wood Screw C-FT-8x180/170

$d = 8 \text{ mm}$, $l = 180 \text{ mm}$

$l_g = 170 \text{ mm}$, $l_{ef} = 165 \text{ mm}$

4 screws

minimum spacing

axially loaded:

(acc. to ETA-22/0789:2023, table A6.4)

$$a_1 = 120 \text{ mm} \geq 5 \cdot d = 5 \cdot 8 = 40 \text{ mm} \rightarrow \text{OK}$$

$$a_2 = 80 \text{ mm} \geq 2.5 \cdot d = 2.5 \cdot 8 = 20 \text{ mm} \rightarrow \text{OK}$$

$$a_1 \cdot a_2 = 120 \cdot 80 = 9600 \text{ mm}^2 \geq 25 \cdot d^2 = 25 \cdot 8^2 = 600 \text{ mm}^2 \rightarrow \text{OK}$$

$$a_{2,c} = 40 \text{ mm} \geq 4 \cdot d = 4 \cdot 8 = 32 \text{ mm} \rightarrow \text{OK}$$

laterally loaded:

According to ETA 22/0789:2023, table A6.12 for laterally loaded screws without drill tip, the spacing of nails without pre-drilled holes can be applied (see EN 1995-1-1, table 8.2). For steel-to-timber connections the minimum spacings can be multiplied by a factor of 0.7 according to EN 1995-1-1, section 8.3.1.4 (1).

$\alpha = 0^\circ$, (load-grain angle for determination of minimum spacing acc. to EN 1995-1-1)

$$a_1 = 120 \text{ mm} \geq 0.7 \cdot (5 + 7 \cdot |\cos \alpha|) \cdot d = 0.7 \cdot (5 + 7 \cdot |\cos 0|) \cdot 8 = 67 \text{ mm} \rightarrow \text{OK}$$

$$a_2 = 80 \text{ mm} \geq 0.7 \cdot (5 \cdot d) = 0.7 \cdot 5 \cdot 8 = 28 \text{ mm} \rightarrow \text{OK}$$

$$a_{4,c} = 40 \text{ mm} \geq 5 \cdot d = 5 \cdot 8 = 40 \text{ mm} \rightarrow \text{OK}$$

determination of the axial load bearing capacity of the single screw

$$F_{ax,Rd,n=1} = \min \left\{ \begin{array}{l} \text{withdrawal resistance} \\ \text{screw tension resistance} \end{array} \right\}$$

STEEL-TO-TIMBER CONNECTION CALCULATION EXAMPLE



design value of the withdrawal resistance:

$$F_{ax,Rd,n=1} = f_{ax,k,90} \cdot k_{ax} \cdot k_{sys} \cdot \left(\frac{\rho_k}{\rho_{k,ref}} \right)^{k_p} \cdot d \cdot l_{ef} \cdot \frac{k_{mod}}{\gamma_M}$$

$f_{ax,k,90}$ 13.1 N/mm² (acc. to ETA-22/0789:2023, table A6.1)

k_{ax} 1.0 for $30^\circ \leq \alpha \leq 90^\circ$

k_{sys} 1.00 for solid wood

ρ_k 350 kg/m³ characteristic density of the timber raw material

$\rho_{k,ref}$ 350 kg/m³ reference characteristic density of the timber raw material

k_p 1.10 for softwood and $15^\circ \leq \alpha \leq 90^\circ$

l_{ef} 165 mm

k_{mod} 0.9 (SC1, duration of load short-term according to EN 1995-1-1)

γ_M 1.30 (for connections in timber construction acc. to EN 1995-1-1, table 2.3)

$$F_{ax,Rd,n=1} = 13.1 \cdot 1.0 \cdot 1.00 \cdot \left(\frac{350}{350} \right)^{1.10} \cdot 8 \cdot 165 \cdot \frac{0.9}{1.30} = 11971 \text{ N}$$

design value of the screw tension resistance:

$F_{tens,k}$ 24100 N (acc. to ETA-22/0789:2023, table A6.1)

γ_{M2} 1.25 (for steel tension failure acc. to EN 1993-1-1:2014, section 6.1)

$$F_{tens,d} = \frac{F_{tens,k}}{\gamma_{M2}} = \frac{24100}{1.25} = 19280 \text{ N}$$

axial load bearing capacity of the single screw:

$$F_{ax,Rd,n=1} = \min \left\{ \begin{array}{l} F_{ax,Rd,n=1} \\ F_{tens,d} \end{array} \right\} = \min \left\{ \begin{array}{l} 11971 \\ 19280 \end{array} \right\} = 11971 \text{ N}$$

determination of the axial connection resistance

n_{ef} $n^{0.9}$ (acc. to EN 1995-1-1, section 8.7.2)

$$F_{ax,Rd} = n_{ef} \cdot F_{ax,Rd,n=1} = 4^{0.9} \cdot 11971 = 41685 \text{ N}$$

determination of the load bearing capacity of the single shear steel-to-timber connection with a thick steel plate

determination of embedment strength and yield moment

(acc. to ETA-22/0789:2023, section A.6.2.3)

α 90° , axis-grain-angle

ε 0° , load-grain-angle

$$f_{h,k} = k_\alpha \cdot k_\beta \cdot k_\varepsilon \cdot f_{h,k,ref}$$

$$k_\alpha = \frac{1}{2.5 \cdot \cos^2(\alpha) + \sin^2(\alpha)} = \frac{1}{2.5 \cdot \cos^2(90) + \sin^2(90)} = 1.0$$

k_β

$$k_\varepsilon = k_{90} \cdot \cos^2(\varepsilon) + \sin^2(\varepsilon) = 1.2 \cdot \cos^2(0) + \sin^2(0) = 1.20$$

FULLY THREADED SCREWS

C.1 wind bracing connection

- k_{90} 1.20 in the member of the point side
 ρ_k 350 kg/m³ characteristic density of the timber element
 $f_{h,k,ref}$ characteristic reference embedment strength of non-predrilled timber elements
 $f_{h,k,ref} = 0.082 \cdot \rho_k \cdot d^{-0.3} = 0.082 \cdot 350 \cdot 8^{-0.3} = 15.4 \text{ N/mm}^2$
 $f_{h,k} = 1.0 \cdot 1.0 \cdot 1.2 \cdot 15.4 = 18.5 \text{ N/mm}^2$
 $M_{y,Rk}$ 20.3 Nm \equiv 20300 Nmm, characteristic yield moment (acc. to ETA-22/0789:2023, table A6.1)

(acc. to EN 1995-1-1, section 8.2.3 with equation 8.10)

The verification is done for a thick steel plate due to the greater thickness t than the screw diameter d . Due to the axial loading in tension of the screws the rope effect is not considered.

$$F_{V,Rd,n=1} = \min \left\{ \begin{array}{l} F_{V,Rd,c} (c) \\ F_{V,Rd,d} (d) \\ F_{V,Rd,e} (e) \end{array} \right\}$$

$$F_{V,Rd,c} = f_{h,k} \cdot t_1 \cdot d \cdot \frac{k_{mod}}{\gamma_M} = 18.5 \cdot 165 \cdot 8 \cdot \frac{0.9}{1.30} = 16906 \text{ N} \quad (c)$$

$$F_{V,Rd} = f_{h,k} \cdot t_1 \cdot d \cdot \left[\sqrt{2 + \frac{4 \cdot M_{y,Rk}}{f_{h,k} \cdot d \cdot t_1^2}} - 1 \right] \cdot \frac{k_{mod}}{\gamma_M}$$

$$= 18.5 \cdot 165 \cdot 8 \cdot \left[\sqrt{2 + \frac{4 \cdot 20300}{18.5 \cdot 8 \cdot 165^2}} - 1 \right] \cdot \frac{0.9}{1.30} = 7106 \text{ N} \quad (d)$$

$$F_{V,Rd,e} = 2.3 \cdot \sqrt{M_{y,Rk} \cdot f_{h,k} \cdot d} \cdot \frac{k_{mod}}{\gamma_M}$$

$$= 2.3 \cdot \sqrt{20300 \cdot 18.5 \cdot 8} \cdot \frac{0.9}{1.30} = 2760 \text{ N} \quad (e)$$

design value of the load bearing capacity of the single shear steel-to-timber connection with a thick steel plate

- n_{90} 2, number of screws in a row (perpendicular to grain)
 n_{ef} effective number of screws parallel to grain (acc. to EN 1995-1-1, equation 8.17)

$$n_{ef} = n^{k_{ef}} = 2^{0.85} = 1.8$$

$$F_{V,Rd} = n_{90} \cdot n_{ef} \cdot F_{V,Rd,n=1} = 2 \cdot 1.8 \cdot \min \left\{ \begin{array}{l} 18740 (c) \\ 7896 (d) \\ 2760 (e) \end{array} \right\} = 2 \cdot 1.8 \cdot 2760 = 9936 \text{ N}$$

STEEL-TO-TIMBER CONNECTION CALCULATION EXAMPLE

verification for combined loading

$$\left(\frac{F_{ax,Ed}}{F_{ax,Rd}}\right)^2 + \left(\frac{F_{V,Ed}}{F_{V,Rd}}\right)^2 \leq 1.0$$

$$\left(\frac{F_{Ed} \cdot \sin(45)}{F_{ax,Rd}}\right)^2 + \left(\frac{F_{Ed} \cdot \cos(45)}{F_{V,Rd}}\right)^2 \leq 1.0$$

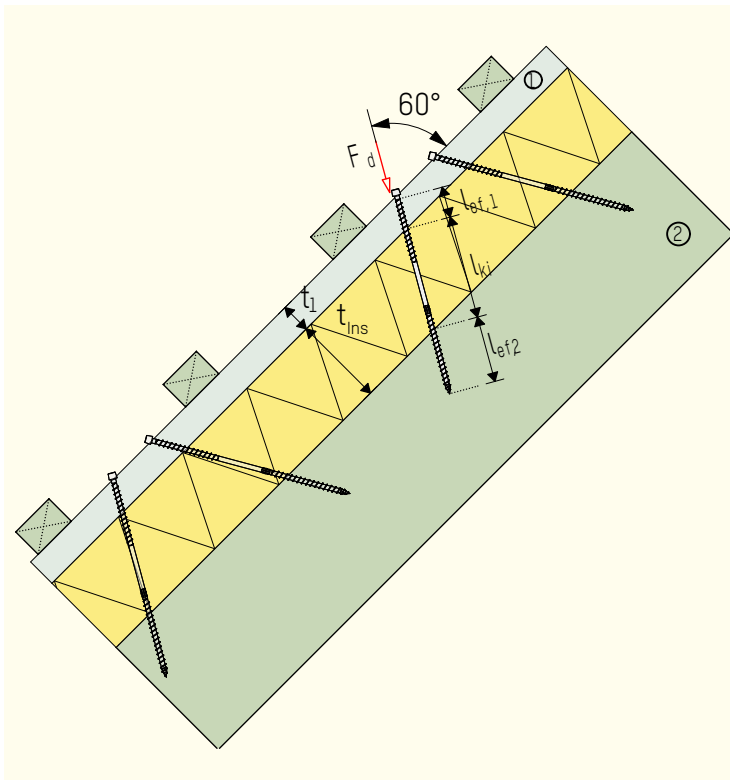
$$\left(\frac{15000 \cdot \sin(45)}{41685}\right)^2 + \left(\frac{15000 \cdot \cos(45)}{9936}\right)^2 \leq 1.0$$

$$0,06 + 1,14 = 1,2$$

verification not fulfilled

FULL OR DOUBLE THREADED SCREW APPLICATION

C.2 Thermal insulation on roof or facade application



DETAILS

service class SC1

loading

permanent load: $F_{G,k} = 0.50$ kN

variable load: $F_{N,k} = 0.75$ kN

(category A, duration of load medium-term)

construction elements

construction elements 1 and 2 solid timber C24

battenboard $t_1 = 40$ mm

on-roof insulation $t_{ins} = 120$ mm

Wood Screw CY-DT-8x260/100+80

$d = 8$ mm, $d_i = 5.3$ mm, $l = 260$ mm

$l_{g,1} = 80$ mm, $l_{g,2} = 100$ mm

can be replaced with: CY-FT-8x260/250

action design value

$$F_{Ed} = \gamma_G \cdot F_{G,k} + \gamma_Q \cdot F_{N,k}$$

$$F_{Ed} = 1.35 \cdot 0.5 + 1.5 \cdot 0.75 = 1.80 \text{ kN} \hat{=} 1800 \text{ N}$$

minimum spacing

(acc. to ETA-22/0789:2023, table A6.4)

k_i 10 mm, assumption of the height of the cylinder head

$$l_{ef,1} = \frac{t_1}{\sin(\alpha)} - k_i = \frac{40}{\sin(60^\circ)} - 10 = 35 \text{ mm} \geq 4 \cdot d = 4 \cdot 8 = 32 \text{ mm} \rightarrow \text{OK}$$

$$l_{ef,1} = l - \frac{(t_1 + t_{ins})}{\sin(\alpha)} = 260 - \frac{(40 + 120)}{\sin(60^\circ)} = 75 \text{ mm} \geq 4 \cdot d = 4 \cdot 8 = 32 \text{ mm} \rightarrow \text{OK}$$

determination of the load bearing capacity of the single screw

$$F_{ax,Rd} = \min \left\{ \begin{array}{l} \text{withdrawal resistance in battenboard (1)} \\ \text{withdrawal resistance in rafter (2)} \\ \text{buckling resistance} \end{array} \right\}$$

design value of the withdrawal resistance in battenboard (1):

$$F_{ax,Rd,1} = f_{ax,k,90} \cdot k_{ax} \cdot k_{sys} \cdot \left(\frac{\rho_k}{\rho_{k,ref}} \right)^{k_p} \cdot d \cdot l_{ef,1} \cdot \frac{k_{mod}}{\gamma_M}$$

$f_{ax,k,90}$ 10.9 N/mm² (acc. to ETA-22/0789:2023, table A6.2)

k_{ax} 1.0 for $30^\circ \leq \alpha \leq 90^\circ$

TIMBER-TO-TIMBER CONNECTION CALCULATION EXAMPLE

$$l_{ef,1} = 35 \text{ mm}$$

$$k_{sys} = 1.00$$

$$k_{mod} = 0.8 \text{ (SC1, duration of load medium-term)}$$

$$\gamma_M = 1.30 \text{ (for connections in timber construction acc. to EN 1995-1-1, table 2.3)}$$

$$F_{ax,Rd,1} = 10.9 \cdot 1.0 \cdot 8 \cdot 35 \cdot \frac{0.8}{1.30} = 1878 \text{ N}$$

design value of the withdrawal resistance in rafter (2):

$$F_{ax,Rd,2} = f_{ax,k,90} \cdot k_{ax} \cdot k_{sys} \cdot \left(\frac{\rho_k}{\rho_{k,ref}} \right)^{k_p} \cdot d \cdot l_{ef,2} \cdot \frac{k_{mod}}{\gamma_M}$$

$$l_{ef,2} = 75 \text{ mm}$$

$$F_{ax,Rd,2} = 10.9 \cdot 1.0 \cdot 1.00 \cdot \left(\frac{350}{350} \right)^{1.10} \cdot 8 \cdot 75 \cdot \frac{0.8}{1.30} = 4025 \text{ N}$$

design value of the buckling resistance:

$$F_{ki,Rd} = \frac{\chi \cdot N_{pl,k}}{\gamma_{M1}}$$

$$l_{ki} = 138 \text{ mm, screw length between battenboard and rafter}$$

$$N_{pl,k} = 2.418 \text{ kN} \equiv 2418 \text{ N, for free length of } l_{ki} = 140 \text{ mm (conservative) from ETA-22/0789:2023, table A9.2}$$

$$\gamma_{M1} = 1.00 \text{ (for stability failure of steel elements acc. EN 1993-1-1:2014, section 6.1)}$$

$$F_{ki,Rd} = \frac{2418}{1.00} = 2418 \text{ N}$$

determination of the connection resistance:

$$F_{ax,Rd} = \min \left\{ \begin{array}{l} F_{ax,Rd,1} \\ F_{ax,Rd,2} \\ F_{ki,Rd} \end{array} \right\} = \min \left\{ \begin{array}{l} 1878 \text{ N} \\ 4025 \text{ N} \\ 2418 \text{ N} \end{array} \right\} = 1878 \text{ N}$$

$$F_{Rd} = n_{ef} \cdot F_{ax,Rd}$$

$$n_{ef} = n_{ef} = n = 1.0 \text{ ETA-22/0789:2023, section A.6.1.1}$$

$$F_{Rd} = 1.0 \cdot 1878 = 1878 \text{ N}$$

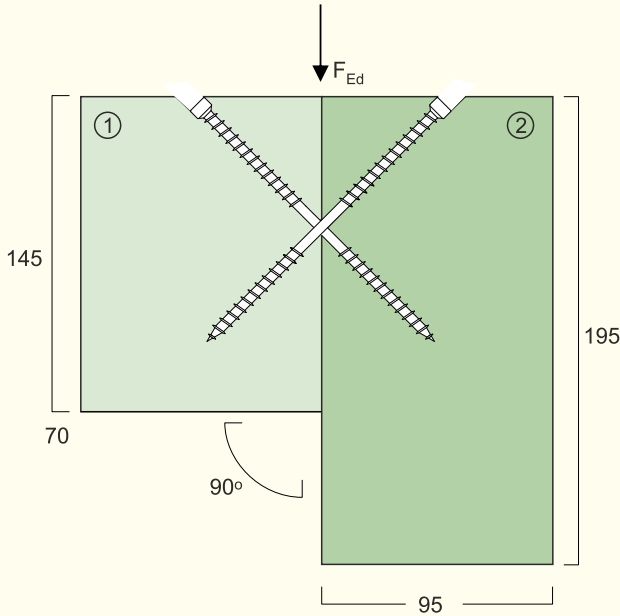
verification

$$F_{Ed} \leq F_{Rd}$$

$$1800 \text{ N} \leq 1878 \text{ N}$$

verification fulfilled (96 %)

Academy: Main-Secondary beam connection



DETAILS

service class SC1

loading

permanent load: $F_{G,k} = 1,2$ kN

variable load: $F_{Q,k} = 3,6$ kN

(category A,

duration of load medium-term)

construction elements

Joist: $b \times h = 70 \times 145$ mm

Beam: $b \times h = 95 \times 195$ mm

solid timber, C24 ($\rho_k = 350 \frac{\text{kg}}{\text{m}^3}$)

wood screw: 1 screw cross =

2 screws, ET-T 8.2x190 mm

$d = 8,2$ mm; $d_1 = 5,7$ mm

$l_d = l_{g,1} = l_{g,2} = 80$ mm

action design value

$$F_{Ed,1} = Y_G \cdot F_{G,k} = 1,35 \cdot 1,2 = 1,62 \text{ kN}$$

$$\rightarrow k_{mod} = 0,6$$

$$F_{Ed,2} = Y_G \cdot F_{G,k} + Y_Q \cdot F_{Q,k} = 1,35 \cdot 1,2 + 1,5 \cdot 3,6 = 7 \text{ kN}$$

$$\rightarrow k_{mod} = 0,8$$

Remark: since the second combination is decisive, further calculation will be done only with it
Partial safety factors [EN -1995-1-1:2025]

$Y_R = 1,3$ Connections with dowel-type fasteners and connectors

$Y_{M1} = 1,1$ Steel design resistance based on a semi-empirical analysis with a ductile failure mode

$Y_{M2} = 1,25$ Steel design resistance of cross-sections in tension to fracture

Geometry and mechanical parameters according to [ETA-26/0158:2026]

$$f_{ax,k,90}(\rho_{ref}) = 15,3 \text{ N/mm}^2$$

$$F_{tens,k} = 30,1 \text{ kN} \mid f_{y,k} = 900 \frac{\text{N}}{\text{mm}^2}$$

$$E_s = 210000 \frac{\text{N}}{\text{mm}^2}$$

Main-Secondary beam connection

design axial tensile and compressive resistance [EN-1995-1-1:2025 - 11.2.2.10]

$$F_{ax,d,t} = \min \left\{ \begin{array}{l} \frac{k_{mod}}{Y_R} \cdot \max(F_{pull,k}; F_{w,k}) \\ \frac{F_{t,k}}{Y_{M2}} \end{array} \right. \rightarrow \min \left\{ \begin{array}{l} \frac{0,8}{1,3} \cdot 9,51 = 5,85 \text{ kN} \\ \frac{30,1}{1,25} = 24,1 \text{ kN} \end{array} \right. \rightarrow 5,85 \text{ kN}$$

$$F_{ax,c,t} = \min \left\{ \begin{array}{l} \frac{k_{mod}}{Y_R} \cdot F_{w,k} \\ \frac{F_{c,k}}{Y_{M1}} \end{array} \right. \rightarrow \min \left\{ \begin{array}{l} \frac{0,8}{1,3} \cdot 9,51 = 5,85 \text{ kN} \\ \frac{13,85}{1,1} = 12,59 \text{ kN} \end{array} \right. \rightarrow 5,85 \text{ kN}$$

→5,85 kN

determination of characteristic head pull-through resistance

Remark: not applicable for ET-T

determination of characteristic withdrawal resistance

$$F_{w,k} = \pi \cdot d \cdot l_d \cdot f_{w,k} = \pi \cdot 8,2 \cdot 80 \cdot 1 \cdot 4,61 = 9,51 \text{ kN}$$

$$f_{w,k} = k_{screw} \cdot k_w \cdot k_{mat} \cdot d^{-0,33} \cdot \left(\frac{\rho_k}{350} \right)^{k^p} = 9,24 \cdot 1 \cdot 1 \cdot 8,2^{-0,33} \cdot \left(\frac{350}{350} \right)^{1,1} = 4,61 \frac{\text{N}}{\text{mm}^2}$$

$$k_{screw} = k_{red} \cdot \frac{f_{ax,k}(\rho_{ref})}{\pi} \cdot \frac{l_d}{l_d - l_p} \cdot \frac{1}{k_w \cdot k_{mat} \cdot d^{-0,33}} = 0,85 \cdot \frac{15,3}{\pi} \cdot \frac{80}{80 - 8,2} \cdot \frac{1}{1 \cdot 1 \cdot 8,2^{-0,33}} = 9,24$$

$$k_{red} = 0,85 \quad [\text{EN -1995-1-1:2025 - M6.3(7)}]$$

$$l_p = 1d = 8,2 \text{ mm} \quad (\text{the length of the tip}) \quad [\text{EN -1995-1-1:2025 - M6.3(7)}]$$

Remark: The default value for k_{screw} is 8.2. Since the ETA-26/0158:2026 provides the characteristic withdrawal parameter $k_{ax,k}$, a transitional calculation for the pullout strength $f_{w,k}$ has been made according to EN 1995-1-1:2025, Annex M6.3.

$k_w = 1$ for $45^\circ \leq \varepsilon \leq 90^\circ$ between the screw axis and the grain direction

Remark: in ETA-26/0158:2026 it is referred as k_{ax}

$k_{mat} = 1$ for solid timber

$k_p = 1,1$ for softwoods and $5^\circ < \varepsilon \leq 90^\circ$

determination of characteristic tensile resistance

$$F_{t,k} = F_{tens,k} = 30,1 \text{ kN} \quad [\text{ETA-26/0158:2026}]$$

determination of characteristic axial compressive resistance

$$F_{c,k} = \Phi_c \cdot N_{pl,k} = 0,6 \cdot 22965,83 = 13,85 \text{ kN} \quad [\text{EN -1995-1-1:2025 (11.5)}]$$

Main-Secondary beam connection

$$\Phi_c = \begin{cases} 1,0 & \text{for } \bar{\lambda} \leq 0,2 \\ \frac{1}{\Phi + \sqrt{\Phi^2 - \bar{\lambda}^2}} & \text{for } \bar{\lambda} > 0,2 \rightarrow \frac{1}{1,07 + \sqrt{1,07^2 - 0,89^2}} = 0,6 \end{cases}$$

$$\Phi = 0,5 \left[1 + 0,49 \cdot (\bar{\lambda} - 0,2) + \bar{\lambda}^2 \right] = 0,5 \left[1 + 0,49 \cdot (0,89 - 0,2) + 0,89^2 \right] = 1,07$$

$$\bar{\lambda} = \sqrt{\frac{N_{pl,k}}{N_{ki,k}}} = \sqrt{\frac{22965,83}{28701,63}} = 0,89$$

$$N_{pl,k} = \pi \cdot \frac{d_1^2}{4} \cdot f_{y,k} = \pi \cdot \frac{5,7^2}{4} \cdot 900 = 22965,83 \text{ N}$$

$$N_{ki,k} = \sqrt{c_h \cdot E_s \cdot I_s} = \sqrt{75,71 \cdot 10881496,24} = 28701,63 \text{ N}$$

$$c_h = (0,19 + 0,012 \cdot d) \cdot \rho_k \cdot \left(\frac{90^\circ + \alpha}{180^\circ} \right) = (0,19 + 0,012 \cdot 8,2) \cdot 350 \cdot \left(\frac{90^\circ + 45^\circ}{180^\circ} \right) = 75,71 \frac{\text{N}}{\text{mm}^2}$$

Remark: the characteristic foundation modulus of the fastener in the Joist is decisive because of the 45 degree angle between the screw axis and the grain direction. Therefore, the value is calculated only for the joist.

$$E_s \cdot I_s = \frac{E_s \cdot \pi \cdot d_1^4}{64} = \frac{210000 \cdot \pi \cdot 5,7^4}{64} = 10881496,24 \text{ N}$$

determination of tension and compression in the fastener

$$F_{t,d} = F_{c,d} = \frac{F_{Ed,2}}{2 \cdot \sin \gamma} = \frac{7}{2 \cdot \sin 45} = 4,95 \text{ kN}$$

verification

$$4,95 \text{ kN} < 5,85 \text{ kN}$$

verification fulfilled (85%)

Remark: Alternatively, the load-carrying capacity of the connection:

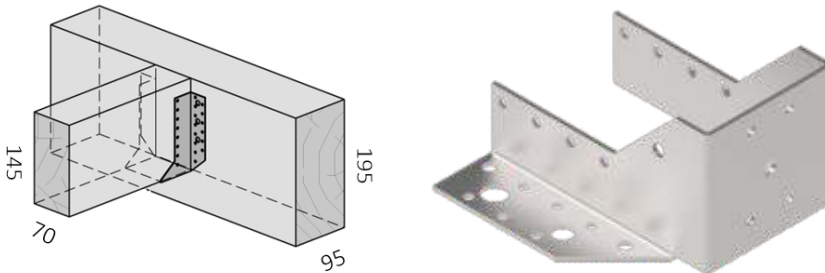
$$F_{R,d} = n_{ef} \cdot F_{ax,d,45^\circ} \cdot \cos 45^\circ = 2 \cdot 5,85 \cdot \frac{\sqrt{2}}{2} = 8,27 \text{ kN} > F_{Ed,2} = 7 \text{ kN}$$

Main-Secondary beam connection

alternative solution according to ETA-23/0235:

joist hanger Blank 320 with external flanges 70/125+ ring-shank nails 4x40 mm

Remark: general principles of joist hanger connection are also given in EN 1995-1-1:2025, G.3.5



determination of the joint hanger connection characteristic resistance, partial nailing

$$F_{z,Rk} = \min \left\{ \frac{(n_J + 2) \cdot F_{v,J,Rk}}{1}, \frac{1}{\sqrt{\left(\frac{1}{n_H \cdot F_{v,H,Rk}}\right)^2 + \left(\frac{1}{k_{H,1} \cdot F_{ax,H,Rk}}\right)^2}} \right\} = \min \left\{ \frac{(4+2) \cdot 157 = 9420}{1}, \frac{1}{\sqrt{\left(\frac{1}{6 \cdot 1570}\right)^2 + \left(\frac{1}{11,1 \cdot 1139}\right)^2}} \right\} = 7554 \rightarrow 7,55 \text{ kN}$$

characteristic lateral resistance per shear plane of a single fastener

$$F_{v,J,Rk} = 1570 \text{ N}$$

characteristic axial tensile resistance of a single fastener

$$F_{ax,H,Rk} = 1139 \text{ N}$$

Remark: the two values above were derived from the information in the ring shank nail DoP form factors of Joist hanger Blank 320 with external flanges [ETA-23/0235, Table B3]

B [mm]	H [mm]	full nailing						partial nailing					
		n_H	n_J	$k_{H,1}$	$k_{H,2}$	e_1 [mm]	e_2 [mm]	n_H	n_J	$k_{H,1}$	$k_{H,2}$	e_1 [mm]	e_2 [mm]
70	125	12	8	23,0	7,43	1631	630	6	4	11,1	3,33	674	303

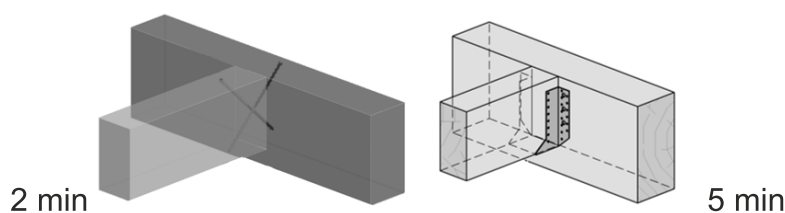
determination of the joint hanger connection design resistance

$$F_{z,Rd} = \frac{k_{mod} \cdot F_{z,Rk}}{\gamma_R} = \frac{0,8 \cdot 7,55}{1,3} = 4,65 \text{ kN}$$

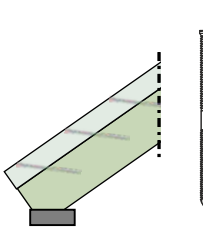
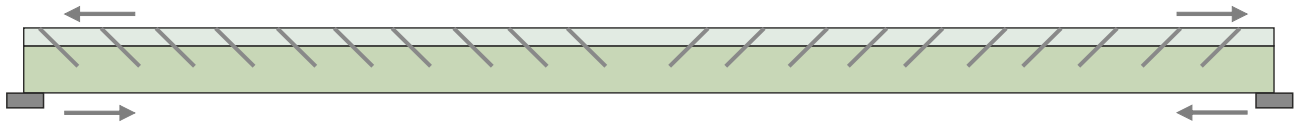
verification

4,95 kN < 7 kN → verification NOT fulfilled (141%) → full nailing needed

tip: installation time

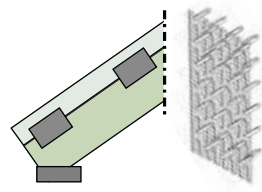


ESSVE double-thread wood screw ET-T fastening system



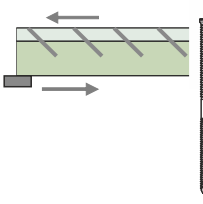
ET-T-6,5x220 mm (possible for Rafter reinforcement)

- 4,8 kN capacity per 1-fastener (Timber 70x45)
- Invisible connection
- Better fire resistance
- Suitable for strengthening existing structures
- Installation: Construction side application



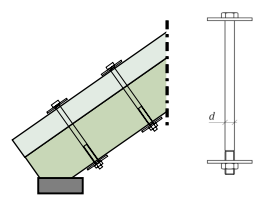
Punched metal plate fastening

- Same load with Plate 100x100mm (both side)
- Visible connection
- No fire resistance without protection
- Rafter strengthening solution (Timber 70x45)
- Installation: Factory application



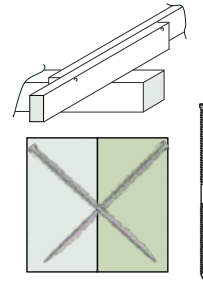
ET-T-8,2x190 mm (possible Main beam reinforcement)

- 4,2 kN capacity per fastener (Timber 70x145+95x145)
- Invisible connection
- Better fire resistance
- Suitable for strengthening existing structures
- Min. Installation time ca. 15 min



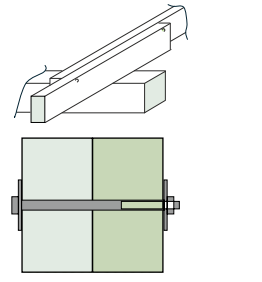
M16 mm (polt-washer-nut connection)

- 8,1 kN capacity per 1-fastener
- Needs predrilling
- Low initial stiffness
- Need for fixing point re-tightening
- Min. Installation time ca. 30 min



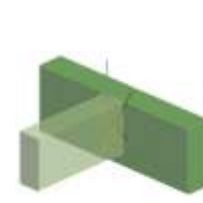
ET-T-8,2x190 mm

- 7 kN shear capacity
- Invisible connection
- Better fire resistance
- Lower total costs and working time
- Shorter installation and calculation time
- Does not need retightening
- Min. Installation time ca. 3-5 min



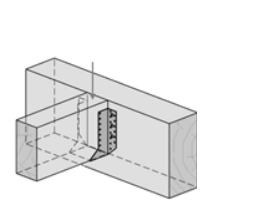
Bolt M16; 4.6

- 9 kN shear capacity
- Needs predrilling
- Low initial stiffness
- Requires re-tightening
- Min. Installation time ca. 7-10 min



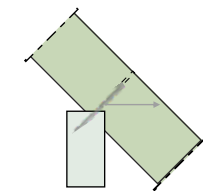
ET-T-8,2x220 mm

- 7 kN shear capacity
- Invisible connection
- Better fire resistance
- Can also be fixed at an angle
- Lower total costs and working time
- Shorter installation and calculation time
- Min. Installation time ca. 1,5-2 min



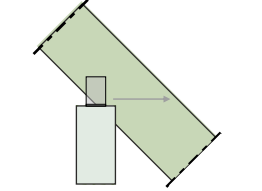
Joist hanger

- Full nailing is needed to achieve the same capacity (partial nailing = 4,7 kN)
- One Joist hanger 70/125 + ring-shank nails 4x40
- Visible connection
- 3x times longer calculation time
- No fire resistance without protection
- Min. Installation time ca. 5 min



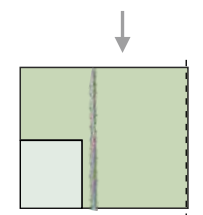
ET-T-6,5x220 mm

- 3 kN capacity with one screw connection
- Invisible connection (timber 45mm)
- Better fire resistance
- Lower total costs and working time
- Shorter installation and calculation time
- Min. Installation time ca. 1 min



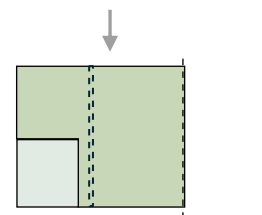
Angle bracket

- Connection is in same value with 2-angle brackets in size of 90x90x65-2,5mm
- 2x times longer calculation time
- Visible connection
- No fire resistance without protection
- Min. Installation time ca. 3 min



ET-T-6,5x190 mm

- 5,3 kN capacity per fastener
- Invisible connection
- Better fire resistance
- Suitable for strengthening existing structures
- Min. Installation time ca. 2 min per 2-fasteners



Rod M12x300 mm

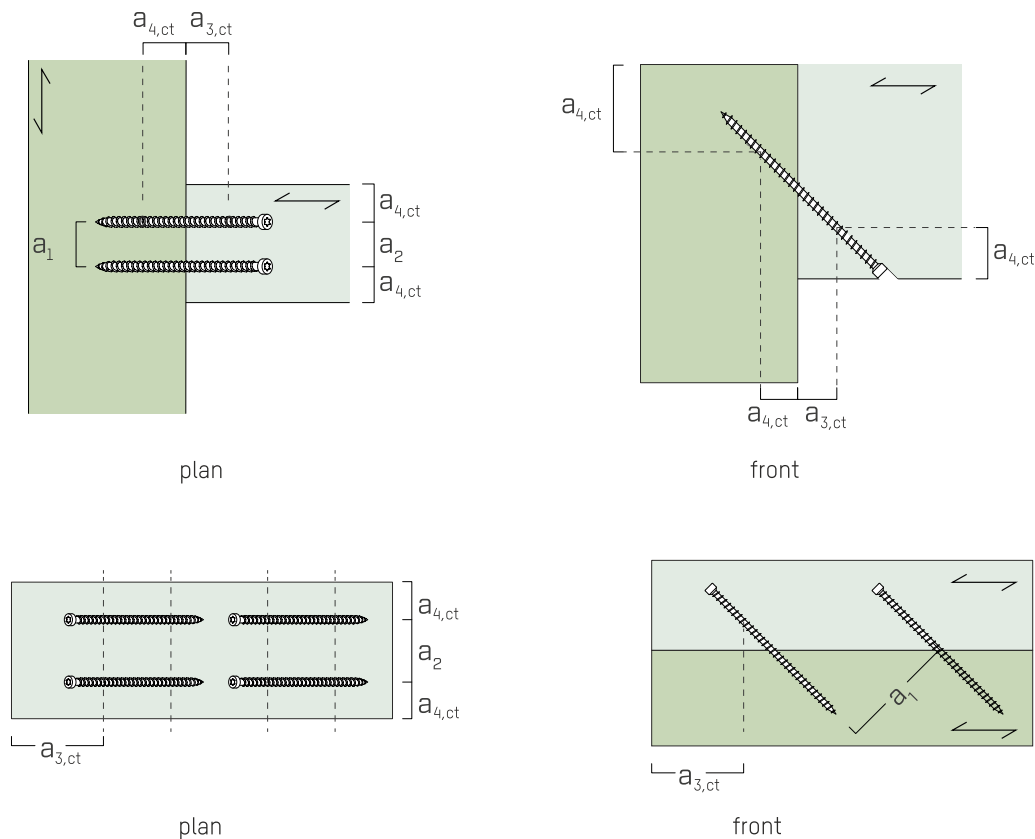
- 11 kN capacity per fastener
- Same load capacity
- Glued-in rod
- Min. Installation time ca. 5 min per 1-glued rod

FOR AXIALLY-LOADED AND INCLINED FASTENERS

Screw family	d (mm)	$a_{1,min}$	$a_{2,min}$	$a_{3,ct,min}$	$a_{4,ct,min}$	a_{cross}	Source
ET-T	6,5	6d	3d	8d	3d	1,5d	ETA-26/0158:2026
ET-T	8,2	7d	5d	10d	4d	1,5d	EN 1995-1-1:2025
C-FT/ CY-FT/ C-PT/ H-PT/W-LF/ C-FH/ CY-DT	8	7d	3d	5d	4d	1,5d	ETA-22/0789:2023
C-FT/ CY-FT/ C-PT/ H-PT/W-LF/ C-FH	10	7d	3d	5d	4d	1,5d	ETA-22/0789:2023
C-FT/ CY-FT/ C-PT/ H-PT/ H-FT	12	7d	3d	5d	4d	1,5d	ETA-22/0789:2023
HF(HEX) / W(WAF) / ESSDRIVE	6	7d	5d	10d	4d	1,5d	EN 1995-1-1:2025
HF(HEX) / W(WAF) / ESSDRIVE	8	7d	5d	10d	4d	1,5d	EN 1995-1-1:2025
HF(HEX) / W(WAF)	10	7d	5d	10d	4d	1,5d	EN 1995-1-1:2025

Spacing of screws, and edge and end distances for screws subjected to Axially loading

Screws under tension inserted with an angle α with respect to the grain

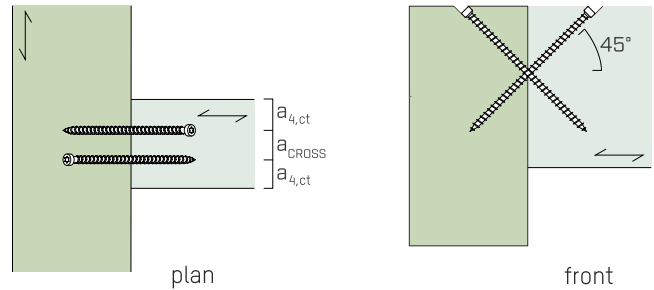
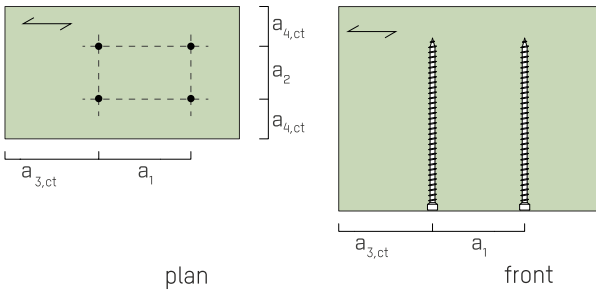


FOR AXIALLY-LOADED AND INCLINED FASTENERS

Screw family	d (mm)	a _{1,min} (mm)	a _{2,min} (mm)	a _{3,ct,min} (mm)	a _{4,ct,min} (mm)	a _{cross} (mm)	Source
ET-T	6,5	40	20	50	20	10	ETA-26/0158:2026
ET-T	8,2	57	41	82	33	12	EN 1995-1-1:2025
C-FT/ CY-FT/ C-PT/ H-PT/W-LF/ C-FH/ CY-DT	8	56	24	40	32	12	ETA-22/0789:2023
C-FT/ CY-FT/ C-PT/ H-PT/W-LF/ C-FH	10	70	30	50	40	15	ETA-22/0789:2023
C-FT/ CY-FT/ C-PT/ H-PT/ H-FT	12	84	36	60	48	18	ETA-22/0789:2023
HF(HEX) / W(WAF) / ESSDRIVE	6	42	30	60	24	9	EN 1995-1-1:2025
HF(HEX) / W(WAF) / ESSDRIVE	8	56	40	80	32	12	EN 1995-1-1:2025
HF(HEX) / W(WAF)	10	70	50	100	40	15	EN 1995-1-1:2025

Screws inserted with $\alpha = 90^\circ$ angle with respect to the grain

Crossed screws inserted with an angle α with respect to the grain



Nomenclature according to Eurocode 5 (EN 1995-1-1:2025) Table 11.22

a _{1,min}	Spacing in a plane parallel to grain
a _{2,min}	Spacing perpendicular to grain
a _{3,ct,min}	End distance of the centroid of lw
a _{4,ct,min}	Edge distance of the centroid of lw
a _{cross}	For crossing fasteners, a minimum distance should be applied

FOR LATERALLY-LOADED SCREWS ACCORDING TO STANDARD EN 1995-1-1:2025 (TABLE 11.16)

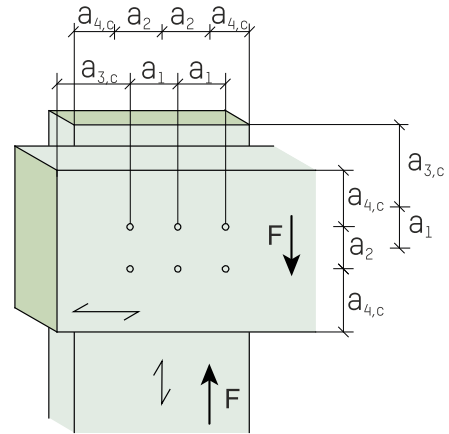
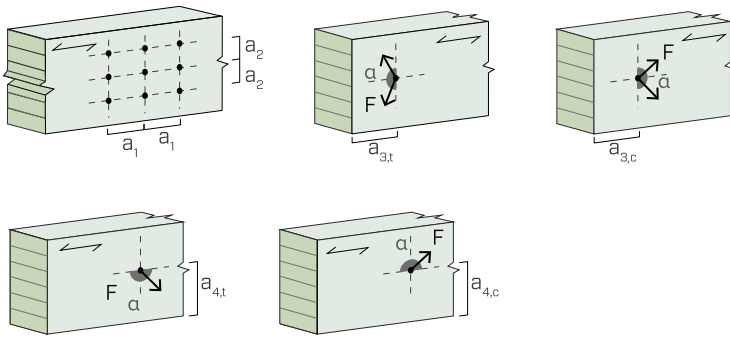
Criteria	a1,min	a2,min	a3,t,min (loaded end)	a3,c,min (unloaded end)	a4,t,min (loaded edge)	a4,c,min (unloaded edge)
Not predrilled						
$\rho_k \leq 430 \text{ kg/m}^3$	10d	5d	15d	10d	7d	5d
$\rho_k > 430 \text{ kg/m}^3$ $\rho_k \leq 500 \text{ kg/m}^3$	15d	7d	20d	15d	12d	7d
Predrilled						
	5d	4d	12d	7d	7d	3d

- Minimum distances in accordance with STANDARD EN 1995-1-1:2025,
- Minimum distances is valid for timber characteristic density of $\leq 420 \text{ kg/m}^3$

- ETA-26/0158:2026; ETA-22/0789:2023
- Hole diameter d_{drill} is valid for softwood.

Spacing of screws, and edge and end distances for screws subjected to lateral loading

Example of edge & end distance definition between two elements in different grain direction



Criteria	a1,min	a2,min	a3,t,min (loaded end)	a3,c,min (unloaded end)	a4,t,min (loaded edge)	a4,c,min (unloaded edge)
Not predrilled						
dw (mm)	6	6,5	8	8,2	10	12
a1 (10d)	60	65	80	82	100	120
a2 (5d)	30	32,5	40	41	50	120
a3,t (15d)	90	97,5	120	123	150	180
a3,c (10d)	60	65	80	82	100	120
a4,t (7d)	42	45,5	56	57,4	70	84
a4,c (5d)	30	32,5	40	41	50	60
With pre-drilled hole						
dw (mm)	6	6,5	8	8,2	10	12
a1 (5d)	30	32,5	40	41	50	60
a2 (4d)	24	26	32	32,8	40	48
a3,t (12d)	72	78	96	98,4	120	144
a3,c (7d)	42	45,5	56	57,4	70	84
a4,t (7d)	42	45,5	56	57,4	70	84
a4,c (3d)	18	19,5	24	24,6	30	36

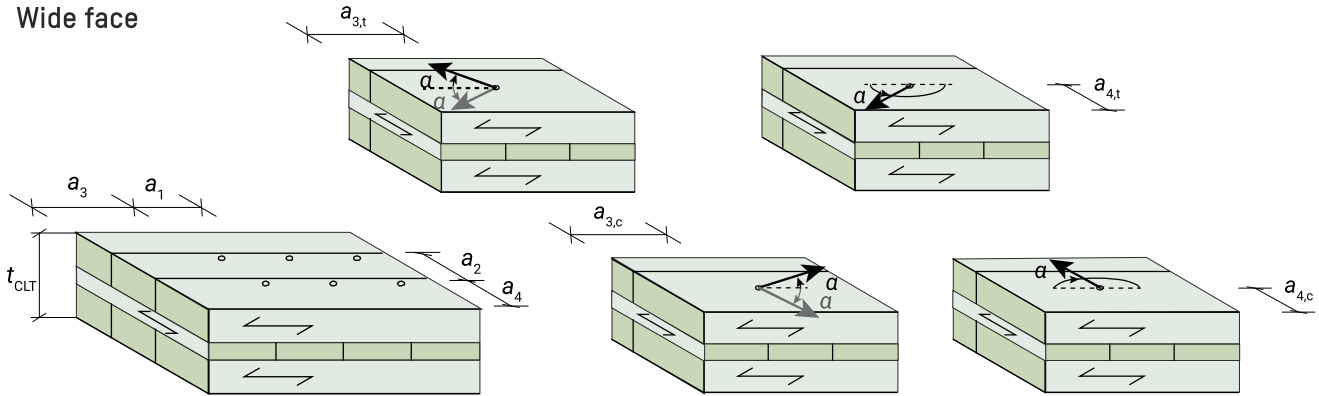
FOR FASTENERS IN CLT EUROCODE 5 (EN 1995-1-1:2025) (TABLE 11.19)

Criteria	a1,min	a2,min	a3,t,min (loaded end)	a3,c,min (unloaded end)	a4,t,min (loaded edge)	a4,c,min (unloaded edge)
Wide face	4d	2.5d	6d	6d	6d	2.5d
Edge face	10d	3d	12d	7d	5d	5d*

*a4,c,min: can be reduced to 3d according to ETA-22/0789 of 13.03.2023 for the following screws:

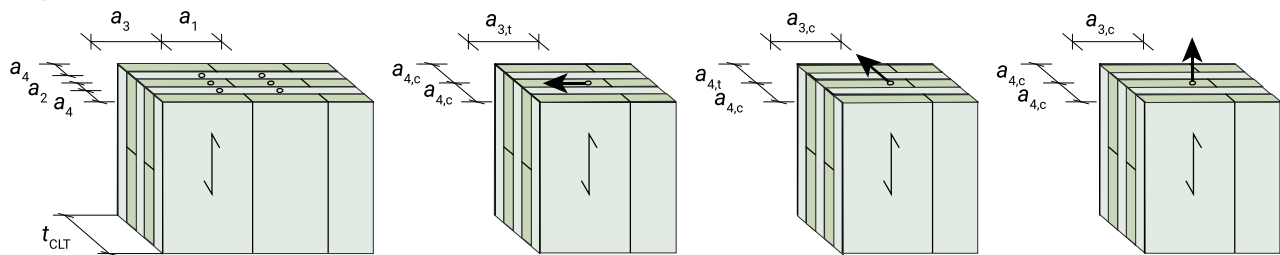
- CY-FT, • C-FT, • C-PT, • H-PT

Wide face



dw (mm)	6	6,5	8	8,2	10	12
WIDE FACE/ Not predrilled						
a1 (4d)	24	26	32	32,8	40	40
a2 (2,5d)	15	16,25	20	20,5	25	30
a3,t (6d)	36	39	48	49,2	60	72
a3,c (6d)	36	39	48	49,2	60	72
a4,t (6d)	36	39	48	49,2	60	72
a4,c cross (2,5d)	15	16,25	20	20,5	25	30

Edge face



dw (mm)	6	6,5	8	8,2	10	12
EDGE FACE / Not predrilled						
a1 (10d)	60	65	80	82	100	120
a2 (3d)	18	19,5	24	24,6	30	36
a3,t (12d)	72	78	96	98,4	120	144
a3,c (7d)	42	45,5	56	57,4	70	84
a4,t (5d)	30	32,5	40	41	50	60
a4,c cross (5d)	15	16,25	20	20,5	25	30

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LATVIA

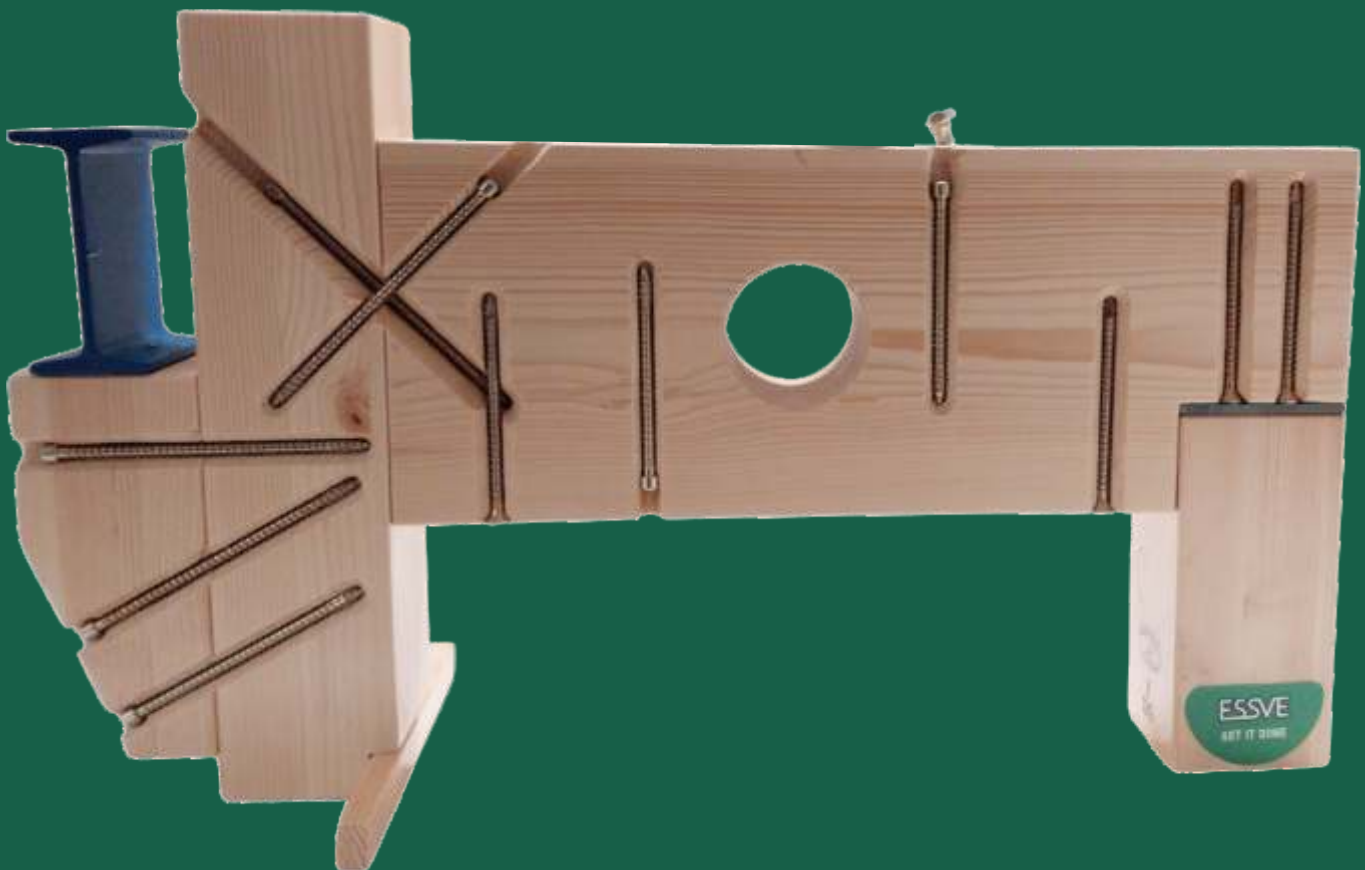
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Safety:

Our screws are approved according to ETA-22/0789 & ETA-26/0158.