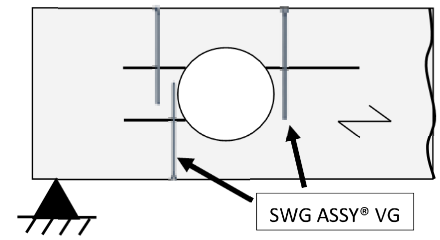
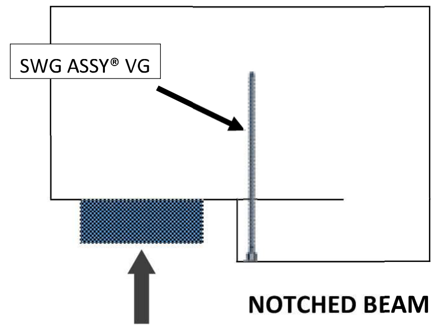
# MyTiCon Timber Connectors White Paper

## Full thread SWG ASSY® Screws as Reinforcement

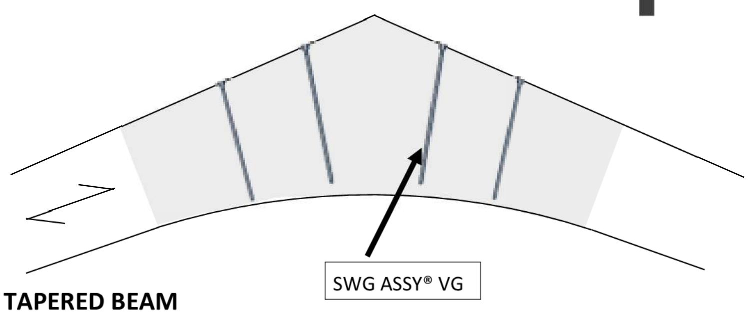
By Max Closen Dipl.-Ing (FH), MaSc



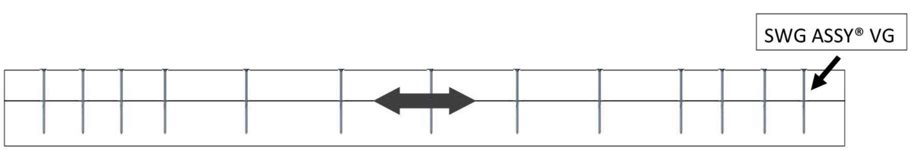

**BEAM WITH OPENINGS**



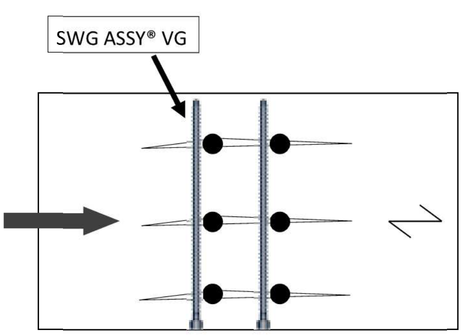

**NOTCHED BEAM**



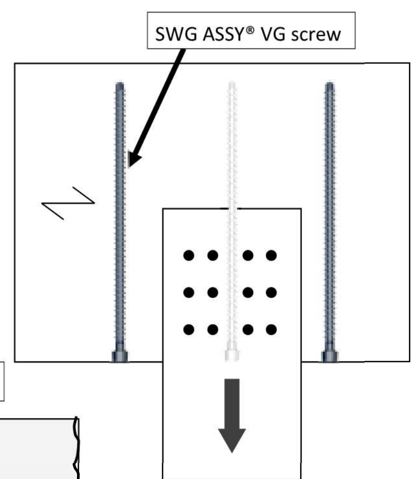

**PITCHED TAPERED BEAM**



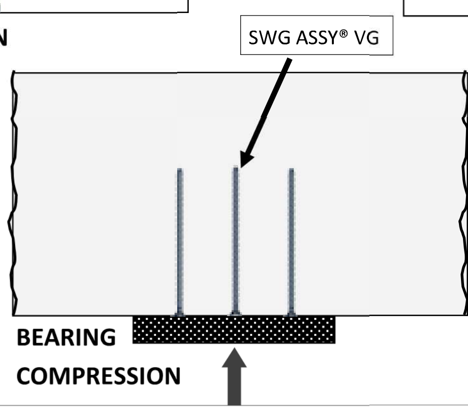

**MECHANICALLY JOINTED BEAM**




**BOLTED CONNECTION**




**PERPENDICULAR CONNECTION**

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## Conditions of use and requirements as reinforcement perpendicular to the grain

External loads on cross connections, notched beams, beams with holes, curved or pitched beams cause stress perpendicular to the grain. As perpendicular to grain splitting is among the weakest properties of wood forces in this direction typically challenge the designer.

Whenever the perpendicular to grain stress exceeds the resistance reinforcement is required.

This document provides design proposals and examples on designing perpendicular to grain reinforcements with full thread screws and does not cover any other potentially required designs of a structural member.

For tensile reinforcement perpendicular to the grain only SWG ASSY® VG screws with full thread shall be used. The screws are driven into the member perpendicular to the contact surface at an angle between screw axis and wood grain of 90°.

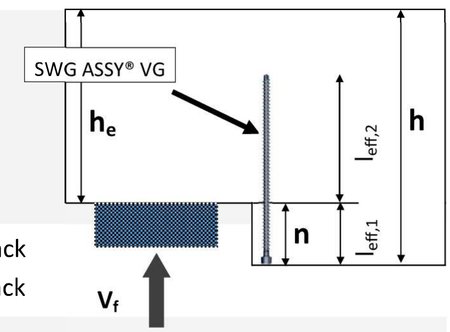
The provided design proposals are only applicable to the following timber species:

- Solid timber [softwood or hardwood (species beech or oak)]
- Glue-laminated timber
- Glued solid timber made of softwood or special hardwood (species beech or oak)
- Laminated Veneer Lumber (LVL)

## Notched beam reinforcement

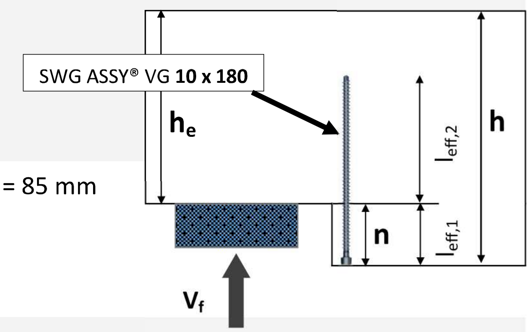
Notched beams experience stress concentrations which may exceed specified capacities of the beam. In these areas a combination of stresses may require beam reinforcement.

Reinforcement can be applied using self-tapping full thread SWG ASSY® VG screws. It is assumed that a check or split has already occurred in the corner of the notch and the entire transverse shear force occurring in the lower portion of the beam is to be transmitted through an axial force component in the screw. In longitudinal direction of the beam only one screw row shall be taken into account.

| **DESIGN** NOTCHED BEAM REINFORCEMENT | |
|---|---|
| *Conditions of use* | rectangular glue-laminated timber member with notch at the tension side at supports |
| *Geometry* | **b** = beam width<br>**h** = beam depth<br>**n** = notch depth<br>$\mathbf{h_e}$ = distance from potential crack to the edge<br> |
| *Effective thread length* | $\mathbf{l_{eff,1}}$ = threaded length below potential crack<br>$\mathbf{l_{eff,2}}$ = threaded length above potential crack |
| *Longitudinal shear resistance [1]* | $\mathbf{F_v} = f_v\ (K_D K_H K_{Sv} K_T)$ [N/mm$^2$] |
| *Maximum shear resistance [1]* | $\mathbf{V_{r,max}}$ |
| *Existing bearing reaction shear force* | $\mathbf{V_f}$ |
| ***CONDITION*** | **IF** $V_f \geq V_{r,\,max}$ **REINFORCEMENT IS REQUIRED** |
| *Factors [2]*<br>*($k_\alpha$ values for standard α ratios are calculated in table 2)* | $\boldsymbol{\alpha = (h_e / h)}$<br>$\boldsymbol{k_\alpha = 1.3 * [3 * (1-\alpha)^2 - 2 * (1-\alpha)^3]}$ |
| *Tensile design force [2] to be transmitted by the reinforcing SWG ASSY® VG screws* | $\boldsymbol{V_{r,t,90} = k_\alpha * V_f}$ |
| *boundary conditions for screw design withdrawal resistance [12]* | <u>effective screw length</u>: $\boldsymbol{l_{eff} = \min\{l_{eff,1}\,;\,l_{eff,2}\}}$<br><u>minimum penetration depth:</u> $\boldsymbol{p_{min} = 4 * D}$ (outside thread diameter) $\boldsymbol{\leq l_{eff}}$<br>(smaller penetration can not be taken into account for beam reinforcement) |
| *Withdrawal resistance of one SWG ASSY® VG screw (refer to table 1)* | $P'_{rw,\alpha} = \min \begin{cases} \textbf{withdrawal resistance } [kN/20\ mm] * l_{eff} \\ \textbf{tensile resistance} \end{cases}$ |
| *Required number of reinforcing screws* [1] | $\boldsymbol{n_{screws} = \sqrt[0.9]{(V_{r,t,90} / P'_{rw,\alpha})}}$ |

<u>*Note:*</u> [1] considering an effective number of screws $n_{eff} = n^{0.9}$ as per [13]
A minimum of 2 screws shall be used whereas only one may be used when minimum penetration depth below and above potential crack is 20*D (=outer thread screw diameter). Required spacing, end and edge distances as per *table 6* to be followed

| **EXAMPLE** NOTCHED BEAM REINFORCEMENT | |
|---|---|
| *Example* | GL 24f-E 215 x 456 mm (8.5 x 18"), $K_D = K_H = K_{Sf} = K_T = 1$, single span over 6 m (19.7') |
| *Geometry* | **b** = 215 mm (8.5")<br>**h** = 456 mm (18")<br>**n** = 100 mm (4")<br>$\mathbf{h_e}$ = 456—100 = 356 mm |
| *Effective thread length* | $\mathbf{l_{eff,1}}$ = 100—15 (unthreaded head) = 85 mm<br>$\mathbf{l_{eff,2}}$ = $l_{screw}$ — n — $l_{tip}$ (=D) =<br>= 180 —100 – 10 = 70 |
| *Longitudinal shear resistance* | $\mathbf{F_v}$ = 2 *1 = 2 N/mm$^2$ |
| *Maximum shear resistance [1]* | $K_N = (1\text{-}100/456)^2 = 0.61$ $A_g = 215 * 456 = 98{,}040$ mm$^2$<br>$\mathbf{V_{r,max}}$ = 0.9 *2 *2/3 *98,040 *0.61 = 71.7 kN |
| *Existing bearing reaction shear force* | $\mathbf{V_f}$ = 100 kN |
| ***CONDITION*** | **100 > 71.7 —> REINFORCEMENT IS REQUIRED** |
| *Factors [2]*<br>*($k_\alpha$ values for standard α ratios are calculated in table 2)* | **α** = (356 /456) = 0.78<br>$\mathbf{k_\alpha}$ = 0.161 (table 2) |
| *Tensile design force [2] to be transmitted by the reinforcing SWG ASSY® VG screws* | $\mathbf{V_{r,t,90}}$ = 0.161 * 100 = 16.1 kN |
| *boundary conditions for screw design withdrawal resistance [12]* | effective screw length: $\mathbf{l_{eff}}$ = min {70 ; 85} = 70 mm<br>minimum penetration depth : $\mathbf{p_{min}}$ = 4 * 10 = 40 < 70 ✓ |
| *Withdrawal resistance of one SWG ASSY® VG screw (refer to table 1)* | $\mathbf{P'_{rw,\alpha}}$ = min { 2.00 kN/20 mm * 70 mm = **<u>7 kN</u>** ; 19.2 kN } |
| *Required number of reinforcing screws* [1] | $\mathbf{n_{screws}} = \sqrt[0.9]{(16.1/7)} = 2.5$ **—> 3 screws** of type SWG ASSY® VG CYL 10 x 180 |

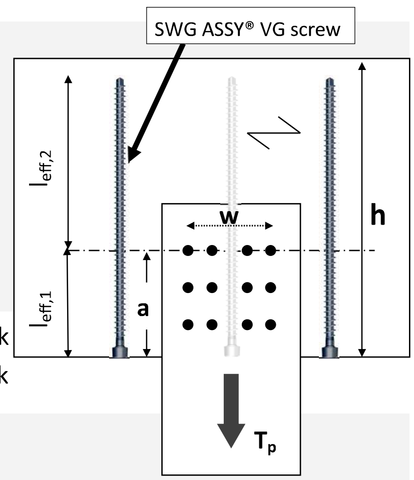



*<u>Note:</u>* [1] considering an effective number of screws $n_{eff} = n^{0.9}$ as per [13]
A minimum of 2 screws shall be used whereas only one may be used when minimum penetration depth below and above potential crack is 20*D (=outer thread screw diameter). Required spacing, end and edge distances as per *table 6* to be followed

## Perpendicular connection members with reinforcement

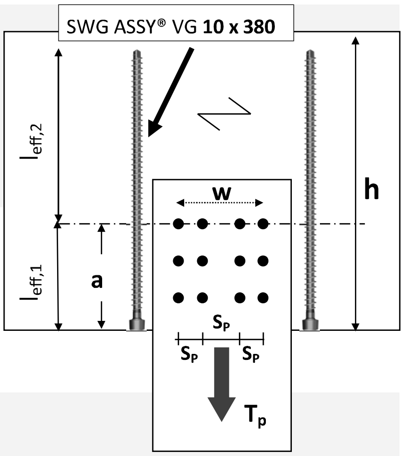
Perpendicular to grain reinforcement may be required to reduce the potential of perpendicular to grain splitting. The zone at risk is in the outer row of fasteners to the edge of the beam.
Reinforcement can be applied using self-tapping full thread SWG ASSY® VG screws.
Outside of the connection only one screw row in longitudinal direction of the beam shall be taken into account.

| **DESIGN** PERPENDICULAR CONNECTION WITH REINFORCEMENT | |
|---|---|
| *Conditions of use* | Perpendicular to grain loaded beam |
| *Geometry* | **b** = beam width [mm]<br>**h** = beam depth [mm]<br>**a** = distance measured from the center of the upper row of fasteners (potential crack) to the loaded edge<br>**w** = width of connection less the included fastener diameters |
| *Effective thread length* | $l_{eff,1}$ = threaded length below potential crack<br>$l_{eff,2}$ = threaded length above potential crack |
| *Tensile strength perpendicular to grain [1]* | $F_{tp} = f_{tp} (K_D K_H K_{Sf} K_T)$ [N/mm²] |
| *Net tension resistance* | $T_{r,tp,max} = \phi\,(=0.7) * F_{tp} * A_n$ **with** $A_n = b * w$ [mm²] |
| *Existing vertical connection shear force* | $T_p$ |
| ***CONDITION*** | **IF** $T_P \geq T_{r,tp,max}$ **REINFORCEMENT IS REQUIRED** |
| *factors [3]*<br>*($k_{tp}$ values for standard α ratios are calculated in table 3)* | $\alpha = (a/h)$<br>$k_{tp} = [1 - 3 * \alpha^2 + 2 * \alpha^3]$ |
| *Tensile design force [3] to be transmitted by the reinforcing SWG ASSY® VG screws* | $T_{r,tp,90} = k_{tp} * T_p$ |
| *boundary conditions for screw design withdrawal resistance [12]* | effective screw length: $l_{eff} = \min\{l_{eff,1}; l_{eff,2}\}$<br>minimum penetration depth: $p_{min} = 4 * D$ (outside thread diameter) $\leq l_{eff}$<br>(smaller penetration can not be taken into account for beam reinforcement) |
| *Withdrawal resistance of one SWG ASSY® VG screw (refer to table 1)* | $P'_{rw,\alpha} = \min \begin{cases} \text{withdrawal resistance [kN/20 mm]} * l_{eff} \\ \text{tensile resistance} \end{cases}$ |
| *Required number of reinforcing screws* [1] | $n_{screws} = \sqrt[0.9]{(T_{r,tp,90} / P'_{rw,\alpha})}$ |




*Note:* [1] considering an effective number of screws $n_{eff} = n^{0.9}$ as per [13]
A minimum of 2 screws shall be used whereas only one may be used when minimum penetration depth below and above potential crack is 20*D (=outer thread screw diameter). Required spacing, end and edge distances as per *table 6* to be followed

**EXAMPLE** PERPENDICULAR CONNECTION WITH REINFORCEMENT




| | |
|---|---|
| *Example* | GL 24f-E 130 x 456 mm (5-1/8 x 18"), $K_D = K_H = K_{Sf} = K_T = 1$,<br>spacing between bolts (10 x 130 mm) is $S_P$ = 152 mm (6"), |
| *Geometry* | **b** = 130 mm (5-1/8")<br>**h** = 456 mm (18")<br>**a** = 305 mm (12")<br>**w** = 3 * $S_p$—3 * d (= bolt diameter) |
| *Effective thread length* | $l_{eff,1}$ = 305—16 (unthreaded head) = 289 mm<br>$l_{eff,2} = l_{screw}$ — a— $l_{tip}$ (≙D) =<br>= 380—305 –10 = 65 mm |
| *Tensile strength perpendicular to grain [1]* | $F_{tp}$ = 0.83 * 1 [N/mm$^2$] |
| *Net tension resistance* | $T_{r,tp,max}$ = 0.7 * 0.83 * 55,380 = 32.1 kN with $A_n$ = 130 * 426 = 55,380 mm$^2$ |
| *Existing vertical connection shear force* | $T_p$ = 45 kN |
| ***CONDITION*** | 45 ≥ 32.1 —> **REINFORCEMENT IS REQUIRED** |
| *Factors [3]*<br>*($k_{tp}$ values for standard α ratios are calculated in table 3)* | **α** = (305/456) = 0.67<br>$k_{tp}$ = 0.255 |
| *Tensile design force [3] to be transmitted by the reinforcing ASSY® VG screws* | $T_{r,tp,90}$ **=** 0.255 * 45 = 11.5 kN |
| *boundary conditions for screw design withdrawal resistance [12]* | effective screw length: $l_{eff}$ **=** min {289 ; 65} = 65 mm<br>minimum penetration depth : $p_{min}$ **=** 4 * 10 = 40 < 65 ✓ |
| *Withdrawal resistance of one SWG ASSY® VG screw (refer to table 1)* | $P'_{rw,\alpha}$ = min { 2.00 kN/20 mm * 65 mm = **6.5 kN** ; 19.2 kN } |
| *Required number of reinforcing screws [1]* | $n_{screws} = \sqrt[0.9]{(11.5 / 6.5)}$ = 1.9 **—> 2 screws** of type SWG ASSY® VG CYL 10 x 380 |

*Note:* [1] considering an effective number of screws $n_{eff} = n^{0.9}$ as per [13]
A minimum of 2 screws shall be used whereas only one may be used when minimum penetration depth below and above potential crack is 20*D (=outer thread screw diameter). Required spacing, end and edge distances as per *table 6* to be followed

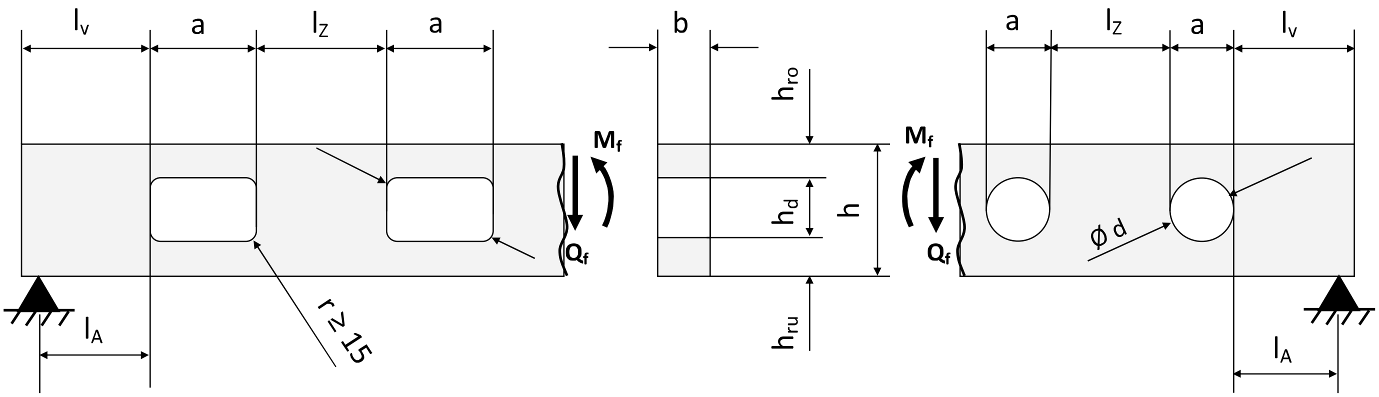
## Reinforcing openings and penetrations

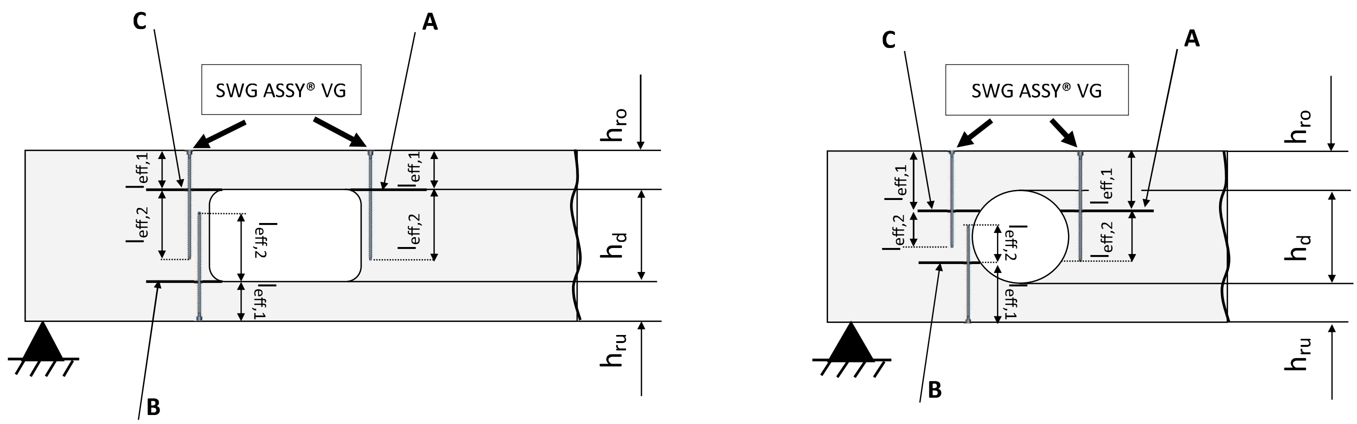
Holes greater d = 50 mm (2”) may weaken the effective cross section so that shear and normal stress travel at the hole are impacted. Resulting forces perpendicular to grain may require reinforcement.

Self-tapping full thread SWG ASSY® VG screws inserted on each side of the hole are a suitable reinforcement method.

| Conditions of use [1] for reinforced beam | | | | | | |
|---|---|---|---|---|---|---|
| $l_v \geq h$ | $l_z \geq$ max {h ; 300 mm} | $l_A \geq h/2$ | $h_{ro\,(ru)} \geq 0.25 * h$ | $a \leq h$ | $a \leq 2.5 * h_d$ | $h_d \leq 0.3 * h$ |

*Note:* [1] according to [4]




*Note:*

**A** potential crack on the **right side** of opening
**B** potential crack on the **left side** of opening, if $F_{t,M,r} \leq F_{t,v,r}$
**C** **additional** potential crack to B on the **left side** of opening, if $F_{t,M,r} > F_{t,v,r}$

right side: side of opening or penetration away from bearing area
left side: side of opening or penetration close to bearing area

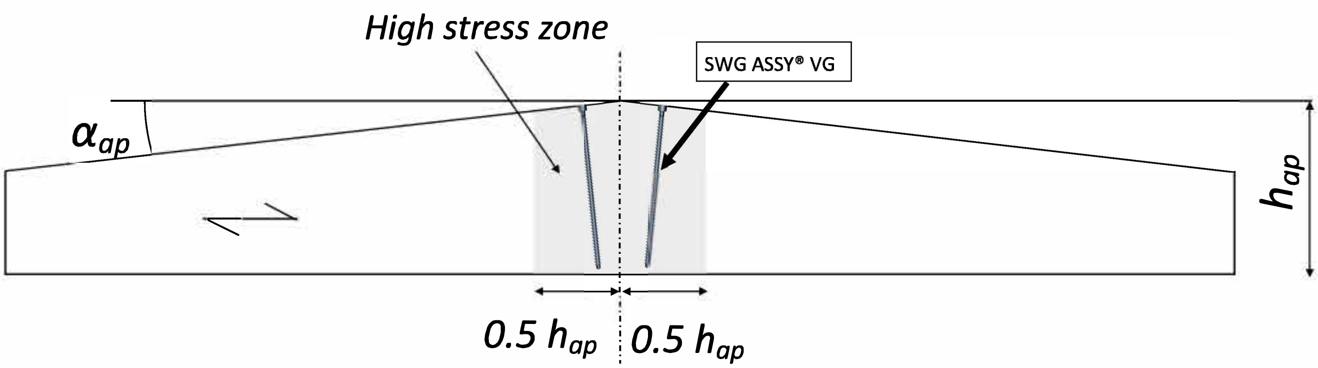
| **DESIGN** REINFORCEMENT FOR BEAMS WITH OPENINGS AND PENETRATIONS | |
|---|---|
| *Conditions of use* | beam with penetration in the high shear zone |
| *Geometry* | **b** = beam width<br>**h** = beam depth<br>**a** = length resp. diameter of the hole |
| *Effective thread length* | Rectangular hole: $l_{eff,1}$ = min {$h_{ro}$ ; $h_{ru}$} less unthread head part<br>$l_{eff,2}$ = remaining threaded length less tip length<br>(tip length = outer thread diameter)<br>Circular hole: $l_{eff,1}$ = min {$h_{ro} + 0.15 * h_d$ ; $h_{ru} + 0.15 * h_d$} less unthread part<br>$l_{eff,2}$ = remaining threaded length less tip length |
| *Tensile strength perpendicular to grain [1]* | $F_{tp} = f_{tp} (K_D K_H K_{Sf} K_T)$ [N/mm$^2$] |
| *Design and reduction factors [5]* | Rectangular hole: $l_{t,90} = 0.5 *(h_d + h)$<br>Circular hole: $l_{t,90} = 0.353 * h_d + 0.5 * h$<br>$k_{t,90} = \min\{ (450/h)^{0.5} ; 1\}$ |
| *Net tension resistance [5]* | $T_{r,tp,max} = 0.5 * l_{t,90} * b * k_{t,90} * \phi (=0.7) * F_{tp}$ |
| *External load at section* | $Q_f$ , $M_f$ |
| *Reduced height [5]* | Rectangular hole: $h_r = \min \{h_{ro} ; h_{ru}\}$<br>Circular hole: $h_r = \min \{h_{ro} + 0.15 * h_d ; h_{ru} + 0.15 * h_d\}$ |
| *Design stress [5] at opening perpendicular-to-grain from shear* | $F_{t,V,r} = (Q_f * h_d) / (4 * h) * [3 — (h_d^2 / h^2)]$ |
| *Design stress [5] at opening perpendicular-to-grain from bending* | $F_{t,M,r} = 0.008 * M_f / h_r$ |
| *Resulting design stress [5] at opening perpendicular-to-grain* | $F_{t,r} = F_{t,V,r} + F_{t,M,r}$ |
| ***CONDITION*** | **IF** $F_{t,r} \geq T_{r,tp,max}$ **REINFORCEMENT IS REQUIRED** |
| *Tensile design force [5] to be transmitted by the reinforcing SWG ASSY® VG screws* [1] | $F_{t,r} = F_{t,V,r} + F_{t,M,r}$ |
| *boundary conditions for screw design with-drawal resistance [12]* | effective screw length: $l_{eff} = \min \{l_{eff,1} ; l_{eff,2}\}$<br>minimum penetration depth: $p_{min} = 4 * D$ (outside thread diameter) $\leq l_{eff}$<br>(smaller penetration can not be taken into account for beam reinforcement) |
| *Withdrawal resistance of **one** SWG ASSY® VG screw (refer to table 1)* | $P'_{rw,\alpha}$ = min { **withdrawal resistance** [kN/20 mm] * $l_{eff}$ ; **tensile resistance** } |
| *Required number of reinforcing screws on one side of the hole* [2] | $n_{screws} = \sqrt[0.9]{(F_{t,r} / P'_{rw,\alpha})}$ |

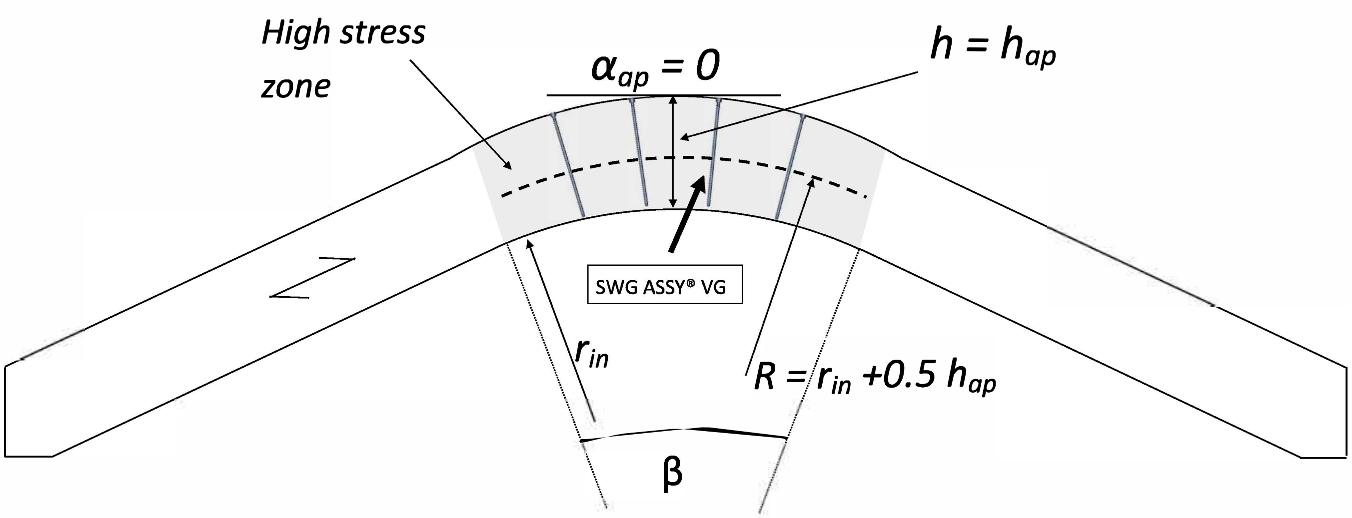
*Note:* [1] Additional reinforcement shall be designed if $F_{t,M,r} > F_{t,V,r}$
[2] considering an effective number of screws $n_{eff} = n^{0.9}$ as per [13]
Screws to be driven in on each side of opening **sufficiently extending into the timber below and above opening.**

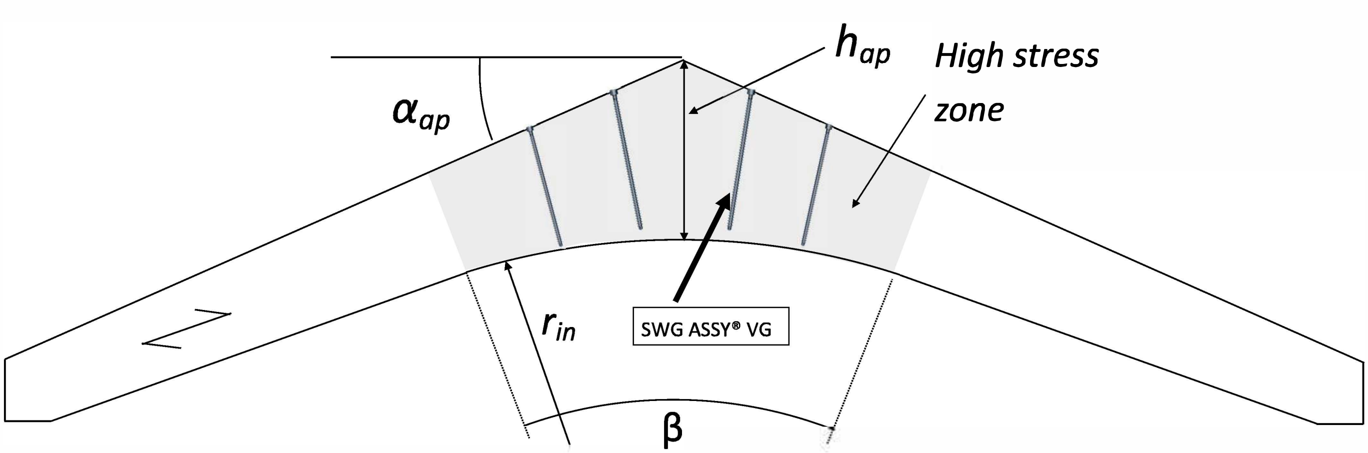
## Reinforcing pitched tapered beams

In pitched tapered beams radial tension stresses often limit the beam slope to 15° or less. Increased bending stress and tensile stress perpendicular-to-grain may occur at the apex cross section.
Reinforcement in the apex area may be applied using self-tapping full thread SWG ASSY® VG screws inserted over the beam depth in the high stressed zone.

Applicable to glue-laminated timber only.



| **DESIGN** PITCHED TAPERED BEAM REINFORCEMENT | |
|---|---|
| *Conditions of use* | Pitched tapered beam with rectangular cross section |
| *Geometry* | **b** = beam width<br>**h** = beam depth<br>$h_{ap}$ = beam depth at the apex<br>$r_{in}$ = inner radius at the apex<br>**r** = $r_{in}$ + 0.5 $h_{ap}$ (radius of curvature at centreline)<br>$\alpha_{ap}$ = angle of the taper in the centre of the apex<br>**β** = enclosed angle in radians |
| *Effective thread length [7]* | **Screws must penetrate the entire beam depth —> $l_{screw} \approx h$**<br>$l_{eff,1}$ = half of the screw length less the unthreaded head part [mm]<br>$l_{eff,2}$ = half of the screw length less 1*D (outer thread diameter) for the tip length [mm] |
| *Tensile strength perpendicular to grain [1]* | $F_{tp} = f_{tp} (K_D K_H K_{Sf} K_T)$ [N/mm²] |
| *Factored bending moment resistance [1] based on radial tension strength* | $M_{rt}$ |
| *Design moment causing tensile stress* | $M_{r,ap}$ |
| ***CONDITION*** | **IF** $M_{r,ap} \geq M_{rt}$ **REINFORCEMENT IS REQUIRED** |
| *Factors [6]* | $k_6 = 0.25 - 1.5 \cdot \tan \alpha_{ap} + 2.6 \cdot \tan^2 \alpha_{ap}$<br>$k_7 = 2.1 \cdot \tan \alpha_{ap} - 4 \cdot \tan^2 \alpha_{ap}$<br>$k_p = 0.2 \cdot \tan \alpha_{ap} + k_6 \cdot (h_{ap}/r) + k_7 \cdot (h_{ap}/r)^2$ |
| *Greatest tensile stress [6] perpendicular-to -grain at the apex due to bending moment* | $\sigma_{r,t,90} = k_p \cdot (6 \cdot M_{r,ap}) / (b \cdot h_{ap}^2)$ [N/mm²] |
| *Spacing of fasteners [7]* | **250 mm ≤ $a_1$ ≤ 0.75 *$h_{ap}$** |
| *Tensile design force [7] to be transmitted by the reinforcing ASSY® VG screws* | $F_{t,r} = \sigma_{r,t,90} \cdot b \cdot a_1$ |
| *boundary conditions for screw design with-drawal resistance [12]* | effective screw length: $l_{eff} = \min \{l_{eff,1}; l_{eff,2}\}$<br>minimum penetration depth: $p_{min}$ = 4 * D (outside thread diameter) ≤ $l_{eff}$<br>(smaller penetration can not be taken into account for beam reinforcement) |
| *Withdrawal resistance of one SWG ASSY® VG screw (refer to table 1)* | $P'_{rw,\alpha}$ = min { **withdrawal resistance** [kN/20 mm] * $l_{eff}$ ; **tensile resistance** } |
| *Required number of reinforcing screws* [1] | $n_{screws} = \sqrt[0.9]{(F_{t,r} / P'_{rw,\alpha})}$ |

*Note:* [1] considering an effective number of screws $n_{eff} = n^{0.9}$ as per [13]
A minimum of 2 reinforcing screws evenly distributed in the highly stressed apex zone shall be applied.
Required spacing, end and edge distances as per *table 6* to be followed.

| **EXAMPLE** PITCHED TAPERED BEAM REINFORCEMENT | |
|---|---|
| *Example* | Pitched double-tapered beam: GL 24f-E 130 x 456 mm (5-1/8 x 18“) |
| *Geometry* | $\mathbf{b}$ = 130 mm (5-1/8”)<br>$\mathbf{h}$ = 456 mm (18”)<br>$\mathbf{h_{ap}}$ = 813 mm (32”)<br>$\mathbf{r_{in}}$ = 2800 mm<br>$\mathbf{r}$ = 2800 + 0.5 *813 = 3206.5 mm<br>$\alpha_{ap}$ = 39°<br>$\beta$ = 51.3° * π/180° |
| *Effective thread length [7]* | $l_{screw}$ ≈ h = 456 mm —> SWG ASSY® VG Cyl 10x430<br>$l_{eff,1}$ = 215—15 = 200 mm<br>$l_{eff,2}$ = 215—10 = 205 mm |
| *Tensile strength perpendicular to grain [1]* | $F_{tp}$ = 0.83 *1 N/mm$^2$ |
| *Factored bending moment resistance [1] based on radial tension strength* | **A** = 130 *813 = 105690 mm$^2$ $K_{Ztp}$ = 0.7 $K_R$ = 7.0<br>$M_{rt}$ = 0.9 *0.83 *(130 *813$^2$ /6) *0.7 *7.0 = **<u>52.4 kNm</u>**<br>($M_{rt}$ = 0.9 *0.83 *2/3 *105690 *3206.5 *0.7 = 118.1 kNm) |
| *Design moment causing tensile stress parallel to the inner curved edge* | $M_{r,ap}$ = 70 kNm |
| ***CONDITION*** | 70 ≥ 52.4 **—> REINFORCEMENT IS REQUIRED** |
| *Factors [6]* | $k_6$ = 0.25 — 1.5 *tan 39 + 2.6 *tan$^2$ 39 = 0.74<br>$k_7$ = 2.1 *tan 39 — 4 *tan$^2$ 39 = - 0.92<br>$k_p$ = 0.2 *tan 39 + 0.74 *(813 /3206.5) —0.92 *(813 /3206.5)$^2$ = 0.29 |
| *Greatest tensile stress [6] perpendicular-to-grain at the apex due to bending moment* | $\sigma_{r,t,90}$ = 0.29 * (6 *70 *10$^6$) /(130 *813$^2$) = 1.42 N/mm$^2$ |
| *Spacing of fasteners [7]* | 250 mm ≤ 355 (14”) ≤ 600 |
| *Tensile design force [7] to be transmitted by the reinforcing ASSY® VG screws* | $F_{t,r}$ = 1.42 *130 *355 = 65.5 kN |
| *boundary conditions for screw design with-drawal resistance [12]* | <u>effective screw length:</u> $l_{eff}$ = min {200 ; 205} = 200 mm<br><u>minimum penetration depth:</u> $p_{min}$ = 4 *10 = 40 < 200 ✓ |
| *Withdrawal resistance of one SWG ASSY® VG screw (refer to table 1)* | $P'_{rw,\alpha}$ = min { 2.00 kN/20 mm * 200 mm = 20 kN ; **<u>19.2 kN</u>** } |
| *Required number of reinforcing screws* [1] | $n_{screws}$ = $^{0.9}\sqrt{(65.5 / 19.2)}$ = 3.9 **—> 4** SWG ASSY® VG Cyl 10x430 **screws** |

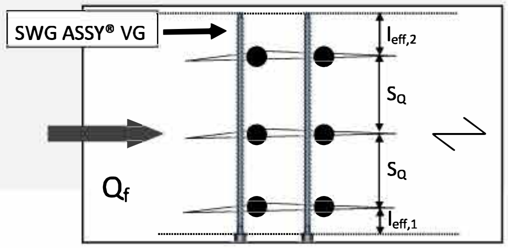
<u>*Note:*</u> [1] considering an effective number of screws $n_{eff} = n^{0.9}$ as per [13]
A minimum of 2 reinforcing screws evenly distributed in the highly stressed apex zone shall be applied.
Required spacing, end and edge distances as per *table 6* to be followed.

## Perpendicular-to-grain splitting reinforcement in bolted connections

Bolted connections with multiple bolts per row may fail brittle due to splitting. Design codes reduce the effective number of bolts by at least 2/3 to reduce brittle failure through splitting.

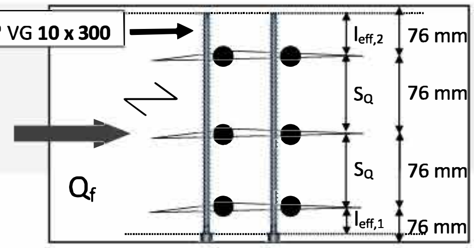
Splitting perpendicular to grain can efficiently be reinforced using self-tapping full thread SWG ASSY® VG screws driven in perpendicular to the bolt axis.
The reinforcing screws with full thread shall be inserted behind the bolt (compression side) as close as possible. The reinforced connection allows to assume all bolts as active and higher connection capacities are achieved.

| **DESIGN** REINFORCEMENT IN BOLTED CONNECTIONS | |
|---|---|
| *Conditions of use* | Bolted connection loaded parallel to grain with reinforcement |
| *Geometry* | **b** = beam width<br>**d** = beam depth<br>$\mathbf{S_Q}$ = spacing between bolts perpendicular to grain<br>$\mathbf{e_L}$ = minimum bolt edge distance |
| *Effective thread length* | $\mathbf{l_{eff,1}}$ = threaded length below lower potential crack<br>$\mathbf{l_{eff,2}}$ = threaded length above upper potential crack less 1*D (=outer thread diameter) for the tip length |
| | |
| *Connection parameters* | $\mathbf{P_r}$ = factored shear resistance of one bolt<br>$\mathbf{n_{sp}}$ = number of shear planes per bolt |
| *Tensile design force [8] perpendicular-to-grain to be transmitted by the reinforcing ASSY® VG screws* | $\mathbf{F_{r,t,90} = n_{sp} * 0.3 * P_r}$ |
| *boundary conditions for screw design withdrawal resistance [12]* | effective screw length: $\mathbf{l_{eff} = \min \{l_{eff,1} ; l_{eff,2}\}}$<br>minimum penetration depth: $\mathbf{p_{min} = 4 * D}$ (outside thread diameter) $\leq \mathbf{l_{eff}}$<br>(smaller penetration can not be taken into account for beam reinforcement) |
| *Withdrawal resistance of one SWG ASSY® VG screw (refer to table 1)* | $P'_{rw,\alpha} = \min \begin{cases} \textbf{withdrawal resistance } [kN/20\ mm] * l_{eff} \\ \textbf{tensile resistance} \end{cases}$ |
| *Required number of reinforcing screws* [1] | $\mathbf{n_{screws} = \sqrt[0.9]{(F_{r,t,90} / P'_{rw,\alpha})}}$ |




Note: [1] considering an effective number of screws $n_{eff} = n^{0.9}$ as per [13]
Reinforcing screws **arranged adjacent to bolts**.
Required spacing, end and edge distances as per *table 6* to be followed.

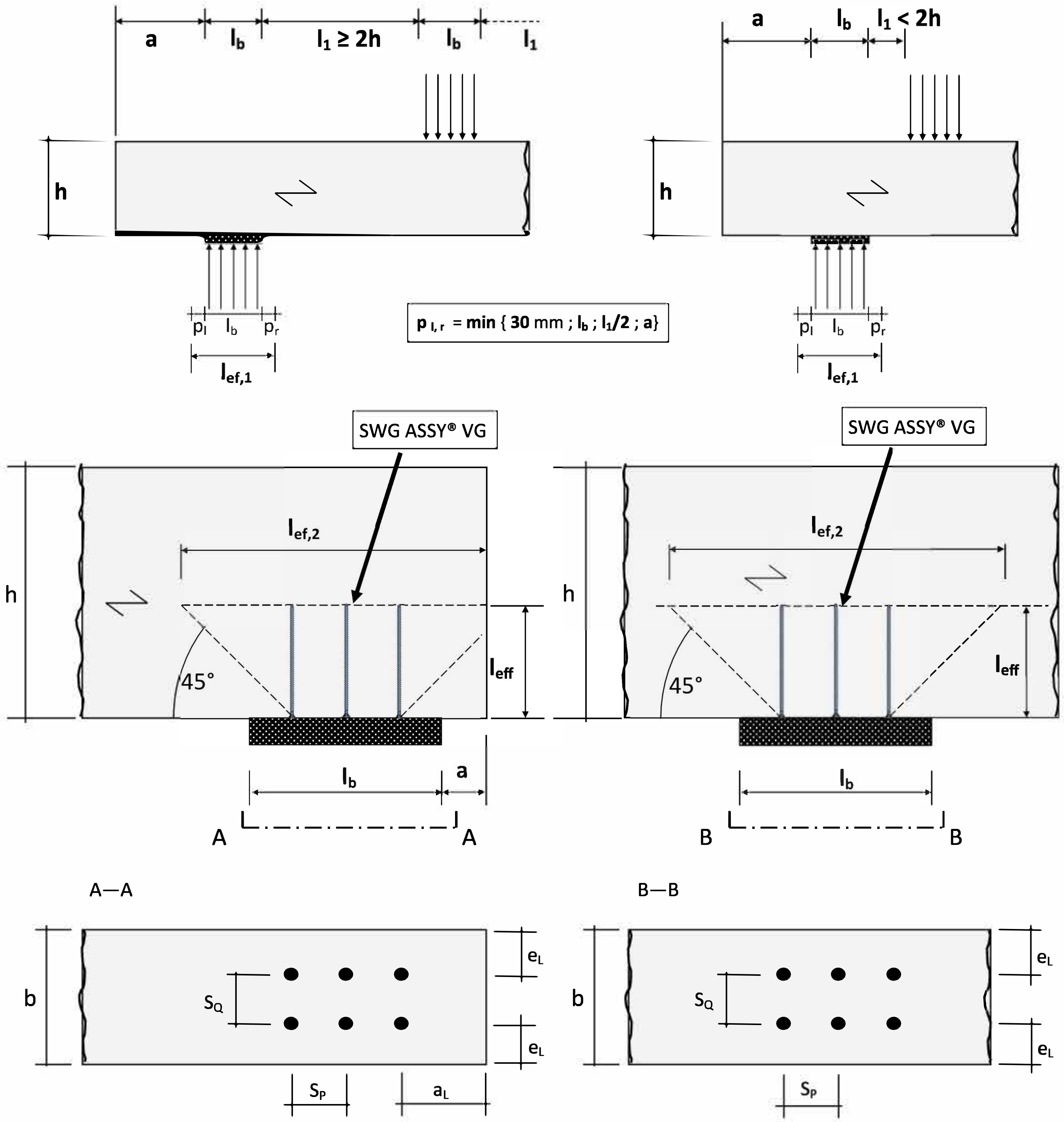
| **EXAMPLE** REINFORCEMENT IN BOLTED CONNECTIONS | |
|---|---|
| *Example* | GL 20f-E 215 x 304 mm (8.5 x 12") connected to a beam with smallest bolt edge distance $e_L$ = 76 mm (3") and bolt spacing perpendicular to grain $S_Q$ = 76 mm (3") , $K_D = K_H = K_{Sf} = K_T = 1$ |
| *Geometry* | **b** = 215 mm (8.5")<br>**d** = 304 mm (12")<br>$\mathbf{S_Q}$ = 76 mm (3")<br>$\mathbf{e_L}$ = 76 mm (3") |
| *Effective thread length* | $\mathbf{l_{eff,1}}$ = 76 — 15 (unthread part) = 61 mm<br>$\mathbf{l_{eff,2}}$ = 300—2*76—76—10 (= tip length) = 62 mm |
| | |
| *Connection parameters* | $\mathbf{P_r}$ = 5.5 kN<br>$\mathbf{n_{sp}}$ = 1 |
| *Tensile design force [8] per bolt perpendicular-to-grain to be transmitted by the reinforcing ASSY® VG screws* | $\mathbf{F_{r,t,90}}$ = 1 * 0.3 * 5.5 = 3.3 kN |
| *boundary conditions for screw design withdrawal resistance [12]* | effective screw length: $\mathbf{l_{eff}}$ = min {61 ; 62} = 61 mm<br>minimum penetration depth : $\mathbf{p_{min}}$ = 4 * 10 = 40 < 61 ✓ |
| *Withdrawal resistance of one SWG ASSY® VG screw (refer to table 1)* | $\mathbf{P'_{rw,\alpha}}$ = min { 2.00 kN/20 mm * 61 mm = **6.1 kN** ; 19.2 kN } |
| *Required number of reinforcing screws* [1] | $\mathbf{n_{screws}} = \sqrt[0.9]{(3.3/6.1)} = 0.51$ **—>** with 2 rows of fasteners **1 screw per row** of type SWG ASSY® VG CYL **10 x 300** shall be used arranged **adjacent to each row of bolts** |




*Note:* [1] considering an effective number of screws $n_{eff} = n^{0.9}$ as per [13]
Reinforcing screws **arranged adjacent to bolts**.
Required spacing, end and edge distances as per *table 6* to be followed.

## Compression reinforcement perpendicular to grain

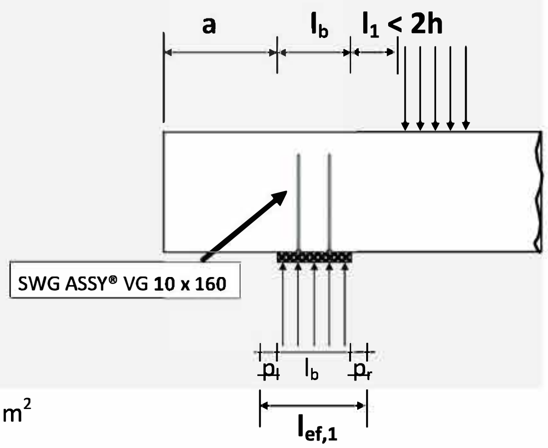
When bearing loads exceed the compression strength of wood perpendicular to grain compression reinforcement may be applied using full thread SWG ASSY® VG screws. The screws are to be driven into the timber member perpendicular to grain top flush with the timber surface and with contact to the bearing plate to distribute the bearing force evenly.



| **DESIGN** COMPRESSION REINFORCEMENT PERPENDICULAR TO GRAIN | |
|---|---|
| *Conditions of use* | End or intermediate beam on discrete support |
| *Geometry* | **b** = beam width<br>**h** = beam depth<br>**a** = distance from compressed area to beam end<br>$\mathbf{l_b}$ = bearing length of support<br>$\mathbf{l_{eff}}$ = threaded length less one outer thread diameter for the tip length<br>$\mathbf{l_1}$ = length between supports or incoming concentrated load<br>$\mathbf{n_0}$ = number of reinforcing screws arranged in a row parallel to grain<br>$\mathbf{S_p}$ = spacing of reinforcing screws in a plane parallel to grain<br>$\mathbf{a_L}$ = end distance of centre of gravity of threaded part in timber member<br>$\mathbf{e_L}$ = edge distance of centre of gravity of threaded part in timber member |
| *Strength in compression perpendicular to grain [1]* | $\mathbf{F_{cp}} = \phi * f_{cp} *(K_D\, K_{Scp}\, K_T\, K_B\, K_{Zcp})$ |
| *Factored compressive resistance perpendicular to grain [1]* | $\mathbf{Q_r}$ |
| *Compressive design force* | $\mathbf{Q_f}$ |
| ***CONDITION*** | **IF** $Q_f \geq Q_r$ **REINFORCEMENT IS REQUIRED** |
| *Effective length of distribution $l_{ef,1}$ [9]* | Effective bearing length (left, right): $\mathbf{p_{l,r}}$ = **min** { **30** mm ; $\mathbf{l_b}$ ; $\mathbf{l_1/2}$ ; **a**}<br>$\mathbf{l_{ef,1} = l_b + p_l + p_r}$ |
| *Compressive reduction factor for discrete supports [9]* | $\mathbf{l_1 < 2h}$: $k_{c,90} = 1.00$<br>$\mathbf{l_1 \geq 2h}$: $k_{c,90} = 1.75$ (glulam with $l_b \leq 400$ mm)<br>$k_{c,90} = 1.50$ (softwood solid sawn)<br>$k_{c,90} = 1.00$ (hardwood) |
| *Design resistance [10] perpendicular-to-grain of a contact area* | $\mathbf{R_{cb,90,d}} = k_{c,90} *b *l_{ef,1} *F_{cp}$ |
| *boundary conditions for screw design compression resistance [12]* | Effective thread penetration length: $\mathbf{l_{eff}}$<br>minimum penetration depth: $\mathbf{p_{min} = 4 * D}$ (outside thread diameter)<br>(smaller penetration can not be taken into account for beam reinforcement) |
| *Compression resistance of one SWG ASSY® VG screw (refer to table 1 and 4)* | $\mathbf{P'_{rw,\alpha}}$ = min { **withdrawal resistance** [kN/20 mm] * $\mathbf{l_{eff}}$ *(refer to table 1)*<br>**tensile resistance** *(refer to table 1)*<br>**buckling resistance of the screw** *(refer to table 4)* |
| *Required number [1] of reinforcing screws [10]* | $\mathbf{n_{screws} = \sqrt[0.9]{([Q_f - R_{cb,90,d}] / P'_{rw,\alpha})}}$ |
| *Effective contact length in the plane of the screw tips $l_{ef,2}$ [10]* | End supports: $\mathbf{l_{ef,2}} = \{l_{eff} + (n_0 - 1) *S_p + \min(l_{eff} ; a_L)\}$<br>intermediate supports: $\mathbf{l_{ef,2}} = \{2 *l_{eff} + (n_0 - 1) *S_p\}$ |
| ***CONDITION** [10]* | $\mathbf{R_{c,tip,90,d}} = b *l_{ef,2} *F_{cp} \geq \mathbf{Q_f}$<br>**—>** otherwise screw length or number to be adjusted |

*Note:* [1] considering an effective number of screws $n_{eff} = n^{0.9}$ as per [13]
Required spacing, end and edge distances as per *table 6* to be followed

| **EXAMPLE** COMPRESSION REINFORCEMENT PERPENDICULAR TO GRAIN | |
|---|---|
| *Example* | GL 24f-E 215 x 456 mm (8.5 x 18”) with an end support<br>potential reinforcement: SWG ASSY® VG CSK **10 x 160** mm |
| *Geometry* | **b** = 215 mm (8.5”)<br>**h** = 456 mm (18”)<br>**a** = 81 mm<br>$l_b$ = 100 mm<br>$l_{eff}$ = 160—10 = 150 mm<br>$l_1$ = 750 mm<br>$n_0$ = 2<br>$S_P$ = 76 mm (3”)<br>$a_L$ = 114 mm (4-1/2”)<br>$e_L$ = 76 mm (3”) |
| *Strength in compression perpendicular to grain [1]* | $F_{cp}$ = 0.8 * 7 *1.0 = 5.6 N/mm² |
| *Factored compressive resistance perpendicular to grain [1]* | $Q_r$ = $K_B$ *$l_b$ *b *$F_{cp}$ = 1.1 *100 *215 *5.6 = 132.4 kN |
| *Compressive design force* | $Q_f$ = 220 kN |
| ***CONDITION*** | 220 ≥ 132.4 **REINFORCEMENT IS REQUIRED** |
| *Effective length of distribution $l_{ef,1}$ [9]* | Effective bearing length (left, right): $p_l$ = min { 30 ; 100 ; 750/2; 81} = 30 mm<br>$p_r$ = min { 30 ; 100 ; 750/2} = 30 mm<br>$l_{ef,1}$ = 100 + 30 + 30 = 160 mm |
| *Compressive reduction factor for discrete supports [9]* | 750 < 2* 456 = 912 mm<br>$k_{c,90}$ = 1.00 |
| *Design resistance [10] perpendicular-to-grain of a contact area* | $R_{c,90,d}$ = 1.00 *215 *160 *5.6 = 192.6 kN |
| *boundary conditions for screw design withdrawal resistance [12]* | Effective thread penetration length: $l_{eff}$ = 150 mm<br>minimum penetration depth: $p_{min}$ = 4 *10 = 40 ≤ 150 ✓ |
| *Compression resistance of one SWG ASSY® VG screw (refer to table 1 and 4)* | $P'_{rw,\alpha}$ = min { 2.00 [kN/20 mm] * 150 = **15 kN** *(refer to table 1)*; 19.2 kN *(refer to table 1)*; 17.07 kN *(refer to table 4)* } |
| *Required number of reinforcing screws [1]* | $n_{screws} = \sqrt[0.9]{[220 - 192.6]/15} = 1.95$<br>—> **2** SWG ASSY® VG CSK **10 x 160 screws** distributed on **2 rows** |
| *Effective contact length in the plane of the screw tips $l_{ef,2}$ [10]* | End supports: $l_{ef,2}$ = {150 + (2—1) *76 + min (150 ; 114)} = 340 mm |
| ***CONDITION** [10]* | $R_{c,tip,90,d}$ = 215 *340 *5.6 = 409 kN ≥ **220 kN** ✓ |

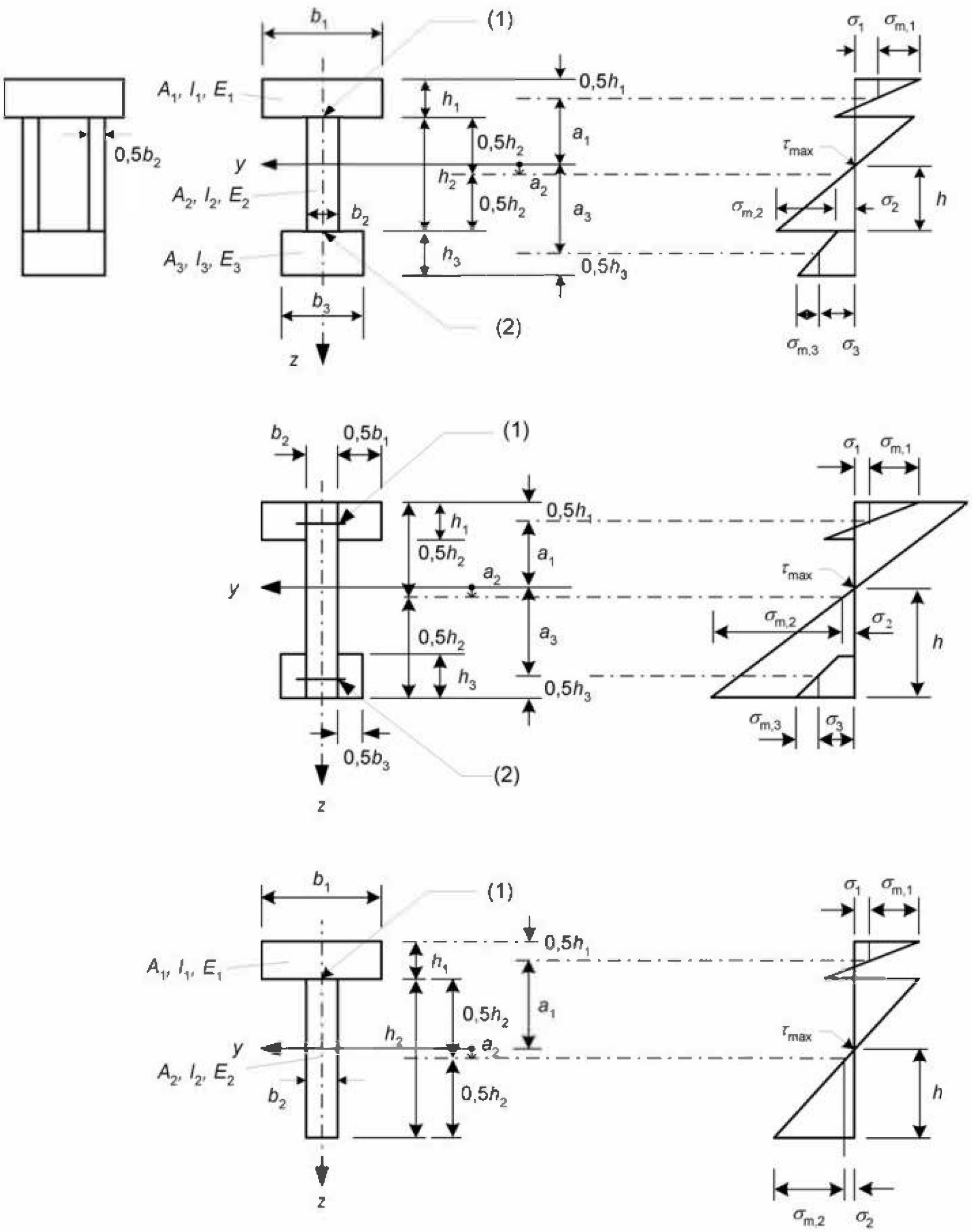



*Note:* [1] considering an effective number of screws $n_{eff} = n^{0.9}$ as per [13]
Required spacing, end and edge distances as per *table 6* to be followed

## Mechanically jointed beam

Upgrading existing beams can be achieved through several methods. One cost efficient approach is to utilise the mechanically jointed beam theory.

High performance SWG ASSY® VG screws have proven to be a simple and easy to apply tool. Strengthening of an existing timber element is achieved through a mechanical bond of the existing beam and the new lamellas screwed on at the top or bottom of the beam.




Key:
(1) spacing: $s_1$ slip modulus: $K_1$ load: $F_1$
(2) spacing: $s_3$ slip modulus: $K_3$ load: $F_3$

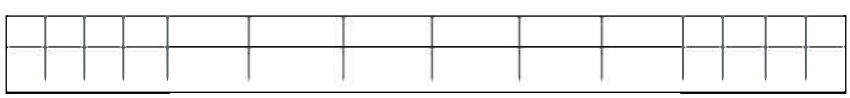
*Picture 1: mechanically jointed beams according to [11]*

## Effective section properties

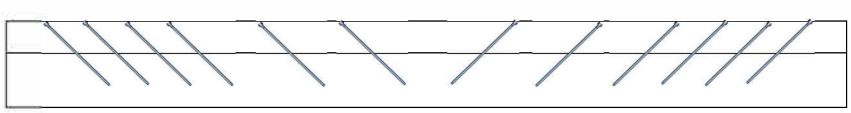
| **EXAMPLE** MECHANICALLY JOINTED BEAM | | |
|---|---|---|
| *Example* | GL 24f-E 130 x 456 mm (5-1/8 x 18”) single span beam of 5.5 m (18’) length with uniform design load of 11.7 kN/m (800 lbf/ft) adding 3 lamellas of 38 mm (1-1/2”) of equal grade | |
| *Geometry* | $\mathbf{b}$ = 130 mm = $b_1$ = $b_2$ | beam width |
| | $\mathbf{h_1}$ = 3 *38 = 114 mm | added member depth |
| | $\mathbf{h_2}$ = 456 mm | original beam depth |
| | $\mathbf{A_1}$ = $b*h_1$ = 130 *114 = 14,820 $mm^2$ | cross section of added member |
| | $\mathbf{A_2}$ = $b*h_2$ = 130 *456 = 59,280 $mm^2$ | cross section of original beam |
| | $\gamma_m$ = 1.3 | material safety factor |
| | $\mathbf{E_{ser}}$ = $E_{mean}$ | Serviceability modulus of elasticity |
| | $\mathbf{E_U}$ = $E_{mean}/\gamma_m$ = 12,800/1.3 = = 9846 N/$mm^2$ = $E_1$ = $E_2$ | Ultimate state design modulus of elasticity |
| | $I_1$ = b * $h_1^3$ /12 = 16,050,060 $mm^4$ | moment of inertia added member |
| | $I_2$ = b * $h_2^3$ /12 = 1,027,203,840 $mm^4$ | moment of inertia original beam |
| | **s** = 152.5 mm (6”) | spacing between fasteners |
| | **D** | Outer thread diameter |
| | $\mathbf{D_{shank}}$ | Shank diameter |
| | Single span beam: $\mathbf{l_{eff} = l_{span}}$ = 5,500 mm | effective span length [11] [multi-span beam: $l_{eff}$ = 0.8 * $l_{span}$ cantilever : $l_{eff}$ = 2 * $l_{cantilever}$ ] |

## Screw arrangements

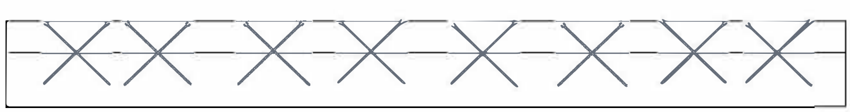
**Version 1**: *partial thread SWG ASSY® Screws inserted perpendicular*



**Version 2**: *full thread SWG ASSY® VG Screws inserted at an angle to the grain of α = 45° (one directional)*



**Version 3**: *full thread SWG ASSY® VG Screws crossed and inserted at an angle to the grain of α = 45°*



## Shear design with partial thread SWG ASSY® Screws [1]

| EXAMPLE MECHANICALLY JOINTED BEAM (Version 1) | |
|---|---|
| *Bearing reaction* | **V** = 11.7 *5.5/ 2 = 32.2 kN |
| ***SHEAR DESIGN * WITH PERPENDICULAR* PARTIAL *THREAD SWG ASSY® SCREWS*** | |
| *angle between screw axis & wood grain* | **α** = 90° |
| *SWG ASSY® screw specifications* | SWG ASSY® Ecofast **10 x 240** ($D_{shank}$ = 7.2 mm) |
| *boundary conditions for screw design **lateral** resistance* | Screw penetration length $l_p$ of SWG ASSY® Ecofast **10 x 240**:<br>$t_1$ = 114 mm — embedment in added member<br>$t_2$ = 240—114—10 = 116 mm — penetration in original beam less one diameter for the tip length<br>$l_p$ **= min** $\{t_1 ; t_2\}$ = 114 mm<br><br>minimum penetration depth:<br>$p_{min}$ **= 4 * D** (outside thread diameter) = 4*10 = 40 < 114 ✓<br>(smaller penetration can not be taken into account for beam reinforcement) |
| *Slip modulus in shear plane* [14]<br>*($\rho_k = 0.84 * SG * 10^3$ : characteristic gravity)* | Serviceability: $K_{ser} = \rho_k^{1.5}/25 * (D_{shank})^{0.8} = (0.84 * 0.49 * 10^3)^{1.5} / 25 * 7.2^{0.8}$ = 1620 N/mm<br>Ultimate state: $K_U = 2/3 * K_{ser}/\gamma_m = 2/3 * 2107/1.3$ = 831 N/mm<br><br>**Ultimate state design**: $K_1 = K_U$ = **831** N/mm ($K_3 = 0$) |
| *Effectivity of added member eccentricity to inertia [11]* ($\gamma_3 = 0$) | $\gamma_1 = \mathbf{1/(1 + \pi^2 * E_1 * A_1 * s/(K_1 * l_{eff}^2))}$<br>$= 1/(1+ \pi^2 * 9{,}846 * 14{,}820 * 152.5/(831 * 5{,}500^2) = 0.1027$ |
| *Effectivity of original beam eccentricity to inertia [11]* | $\gamma_2 = 1$ |
| *Distance of single member **i** centre of gravity to neutral stress axis [11]*<br>*($a_3 = 0$)* | $a_2 = \mathbf{\gamma_1 * E_1 * A_1 * (h_1 + h_2)/ [2*(\gamma_1 * E_1 * A_1 + 1 * E_2 * A_2 + \gamma_3 * E_3 * A_3)]}$<br>$= 0.1027 * 9{,}846 * 14{,}820 * (114 + 456)]/ [2*(0.1027 * 9{,}846 * 14{,}820 + 9{,}846 * 59{,}280)]$<br>$= 7.13$ mm<br>$a_1 = \mathbf{(h_1 + h_2) /2 - a_2} = (114 + 456)/2 - 7.13 = 277.87$ mm |
| *Effective moment of inertia [11]* | $I_{eff} = \mathbf{(I_1 + \gamma_1 * A_1 * a_1^2) + (I_2 + 1 * A_2 * a_2^2) + (I_3 + \gamma_3 * A_3 * a_3^2)}$<br>$= (16{,}050{,}060 + 0.1027 * 14{,}820 * 277.87^2) + (1{,}027{,}203{,}840 + 1 * 59{,}280 * 7.13^2)$<br>$= 1{,}163{,}784{,}856$ mm$^4$<br><br>$(EI)_{eff} = \mathbf{(E_1 * I_1 + E_1 * \gamma_1 * A_1 * a_1^2) + (E_2 * I_2 + E_2 * 1 * A_2 * a_2^2) + (E_3 * I_3 + E_3 * \gamma_3 * A_3 * a_3^2)}$<br>$= E * I_{eff} = 11{,}458{,}625{,}690{,}000$ Nmm$^2$ |
| ***Lateral resistance** [1] of one SWG ASSY® VG screw* | $P_{r,v}$ = **minimum of shear failure modes** ($K_D = K_H = K_{Sf} = K_T = 1$)<br>= 2.62 kN (mode g with 114 mm penetration) |
| ***Lateral design force** [11] to be transmitted by **one vertical inserted ASSY® screw** [1]*<br>***(α = 90°) —> Version 1*** | $V_{v,1} = \mathbf{V * (E_1 * \gamma_1 * A_1 * a_1 * s) / (EI)_{eff}}$<br>$= 32.2 * (9{,}846 * 0.1027 * 14{,}820 * 277.87 * 152.5) / 11{,}458{,}625{,}690{,}000$<br>= 1.78 kN per screw<br>$V_{v,3} = \mathbf{V * (E_3 * \gamma_3 * A_3 * a_3 * s) / (EI)_{eff}} = 0$ |
| $P_{r,v}$ = 2.62 kN ≥ $V_{v,1}$ = 1.78 kN ✓ | |

*Note:* [1] To consider **fastener interaction** the required number of **screws per meter** as per shear design above should be **increased** according to [13] as follows: $n_{req} = \sqrt[0.9]{n_{per\,m}}$

Required spacing, end and edge distances as per *table 6* to be followed

## Shear design with full thread SWG ASSY® VG Screws [1]

| | |
|---|---|
| **EXAMPLE** MECHANICALLY JOINTED BEAM (Version 2 & 3) | |
| *Extern bearing reaction force* | **V** = 11.7 *5.5/ 2 = 32.2 kN |
| ***SHEAR DESIGN * WITH INCLINED* FULL *THREAD SWG ASSY® VG SCREWS*** | |
| *angle between screw axis & wood grain* | **α** = 45° |
| *SWG ASSY® screw specifications* | SWG ASSY® VG **8 x 330** |
| *boundary conditions for screw design **withdrawal** resistance [12]* | penetrated screw length of SWG ASSY® VG Cyl. **8 x 330**:<br>$l_{eff,1}$ = √2 *114—15 = 146 mm — thread penetration in added member less un-threaded head<br>$l_{eff,2}$ = 330—√2 *114—8 = 160 mm — thread penetration in original beam less one diameter for the tip length<br>**$l_p$ = min {$l_{eff,1}$ ; $l_{eff,2}$}** = 146 mm<br>minimum penetration depth:<br>**$p_{min}$ = 4 * D** (outside thread diameter) = 4*8 = 32 < 146 ✓<br>(smaller penetration can not be taken into account for beam reinforcement) |
| *Slip modulus* [15,16]<br>*(ser: serviceability design*<br>*U: ultimate design)* | Serviceability: **$K_{ser}$** = 780 *$D^{0.2}$ /(1/$l_{eff,1}^{0.4}$ + 1/$l_{eff,2}^{0.4}$) = 780*$8^{0.2}$/(1/$146^{0.4}$ + 1/$160^{0.4}$) = 4419 N/mm<br>Ultimate state: **$K_U$** = 2/3 *$K_{ser}$/$\gamma_m$ = 2266 N/mm<br>Slip modulus in shear plane (**ultimate state design**)<br>**$K_1$** = $K_U$ * $\cos^2\alpha$ = 1185 * (cos 45)$^2$ = **1133** N/mm |
| *Effectivity of added member eccentricity to inertia [11]* ($\gamma_3$ = 0) | **$\gamma_1$ = 1/(1 + $\pi^2$ * $E_1$* $A_1$*s/($K_1$ * $l_{eff}^2$))**<br>= 1/(1+ $\pi^2$ * 9,846* 14,820*152.5/(1133 * 5,500 $^2$) = 0.1350 |
| *Effectivity of original beam eccentricity to inertia [11]* | **$\gamma_2$** = 1 |
| *Distance of single member **i** centre of gravity to neutral stress axis [11]*<br>*($a_3$ = 0)* | **$a_2$ = [$\gamma_1$*$E_1$*$A_1$*($h_1$ + $h_2$)/[2*($\gamma_1$*$E_1$*$A_1$ + 1 *$E_2$*$A_2$ + $\gamma_3$*$E_3$*$A_3$)]**<br>= [0.1350*9,846*14,820*(114 + 456)]/ [2*(0.1350*9,846*14,820 + 9,846*59,280)]<br>= 9.30 mm<br>**$a_1$ = ($h_1$ + $h_2$) /2— $a_2$** = (114 + 456)/2— 9.30= 275.7 mm |
| *Effective moment of inertia [11]* | **$I_{eff}$ = ($I_1$ + $\gamma_1$ *$A_1$ *$a_1^2$) + ($I_2$ + 1 *$A_2$ *$a_2^2$) + ($I_3$ + $\gamma_3$ *$A_3$ *$a_3^2$)**<br>= (16,050,060 + 0.1350 *14,820 *275.7 $^2$) + (1,027,203,840 + 1 *59,280 *9.30 $^2$)<br>= 1,200,455,215 $mm^4$<br>**$(EI)_{eff}$ = ($E_1$ *$I_1$ + $E_1$ *$\gamma_1$ *$A_1$ *$a_1^2$) + ($E_2$ *$I_2$ + $E_2$ *1 *$A_2$ *$a_2^2$) + 0**<br>= E *$I_{eff}$ = 11,819,682,040,000 $Nmm^2$ |
| ***Withdrawal resistance** of one SWG ASSY® VG screw (refer to table 1)* | **$P'_{r,w,\alpha}$ = min {** **withdrawal resistance** [1.37 kN/20 mm] * 146 = **10 kN** ; **tensile resistance:** 19.2 kN |
| ***Tensile design force** $V_{t,i}$ [11] to be transmitted by **one inclined** reinforcing **ASSY® VG screw** [1]*<br>***(α = 45°) —> Version 2***<br>*($V_{v,3}$ = $V_{t,3}$ = 0)* | **$V_{v,1}$ = V *($E_1$ *$\gamma_1$ *$A_1$ *$a_1$*s) / $(EI)_{eff}$**<br>= 32.2 *(9,846 *0.1350 *14,820 *275.7 *152.5) /11,819,682,040,000<br>= 2.26 kN per screw<br>**$V_{t,1}$ = $V_{v,1}$ / (cos α)** = 1.78 / cos 45 = 3.19 kN per screw |
| $P_{r,v}$ = 10 kN ≥ **$V_{v,1}$** = 3.19 kN ✓ | |
| ***Tensile design force** $V_{t,i}$ [11] to be transmitted by **one crossed** reinforcing **ASSY® VG screw** [1]*<br>***—> Version 3*** | **$V_{t,1}$ = $V_{v,1}$ / (2 *cos α)** = 2.26 / (2*cos 45) = 1.60 kN per screw |
| $P_{r,v}$ = 10 kN ≥ **$V_{v,1}$** = 1.60 kN ✓ | |

*Note:* [1] To consider **fastener interaction** the required number of **screws per meter** as per shear design above should be **increased** according to [13] as follows: $n_{req} = {}^{0.9}\sqrt{n_{per\,m}}$ . Required spacing, end and edge distances as per *table 6* to be followed

## Design tables for SWG ASSY® VG screws

*Table 1: Factored withdrawal resistance of SWG ASSY® VG screws in kN per 20 mm of thread penetration*

| Factored withdrawal resistance * $P'_{rw,\alpha}$ per 20 mm of thread penetration in kN (only applicable to SWG ASSY® VG screws) | | | | | | | |
|---|---|---|---|---|---|---|---|
| Screw diameter in mm | Mean oven dry relative density | | | | | | Factored tensile resistance in kN |
| | 0.35 | 0.42 | 0.44 | 0.46 | 0.49 | 0.50 (PSL) | |
| | *α ** = 90°* | | | | | | |
| **6** | 0.63 | 0.91 | 0.97 | 1.06 | 1.20 | 0.70 | **9.04** |
| **8** | 0.85 | 1.22 | 1.29 | 1.41 | 1.60 | 0.94 | **15.12** |
| **10** | 1.06 | 1.52 | 1.61 | 1.76 | 2.00 | 1.17 | **19.2** |
| **12** | 1.27 | 1.83 | 1.94 | 2.12 | 2.40 | 1.41 | **24** |
| | *α ** = 45°* | | | | | | |
| **6** | 0.54 | 0.78 | 0.83 | 0.91 | 1.03 | 0.60 | **9.04** |
| **8** | 0.73 | 1.04 | 1.11 | 1.21 | 1.37 | 0.80 | **15.12** |
| **10** | 0.91 | 1.31 | 1.38 | 1.51 | 1.71 | 1.00 | **19.2** |
| **12** | 1.09 | 1.57 | 1.66 | 1.81 | 2.06 | 1.21 | **24** |

Note: * resistance as per [12]
** α: angle between wood grain and screw axis

*Table 2: values of $k_\alpha$ for standard beam sizes and connections*

| Values for $k_\alpha$ with respect to the ratio $h_e$ /h | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **$h_e$ /h** | **0._0** | **0._1** | **0._2** | **0._3** | **0._4** | **0._5** | **0._6** | **0._7** | **0._8** | **0._9** |
| **0.5_** | 0.650 | 0.631 | 0.611 | 0.592 | 0.572 | 0.553 | 0.534 | 0.514 | 0.495 | 0.476 |
| **0.6_** | 0.458 | 0.439 | 0.420 | 0.402 | 0.384 | 0.366 | 0.349 | 0.331 | 0.314 | 0.297 |
| **0.7_** | 0.281 | 0.265 | 0.249 | 0.233 | 0.218 | 0.203 | 0.189 | 0.175 | 0.161 | 0.148 |
| **0.8_** | 0.135 | 0.123 | 0.111 | 0.100 | 0.089 | 0.079 | 0.069 | 0.060 | 0.052 | 0.044 |
| **0.9_** | 0.036 | 0.030 | 0.024 | 0.018 | 0.013 | 0.009 | 0.006 | 0.003 | 0.002 | 0.000 |

*Table 3: values of $k_{tp}$ for standard beam sizes and connections*

| Values for $k_{tp}$ with respect to the ratio a /h | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **a /h** | **0._0** | **0._1** | **0._2** | **0._3** | **0._4** | **0._5** | **0._6** | **0._7** | **0._8** | **0._9** |
| **0.5_** | 0.500 | 0.485 | 0.470 | 0.455 | 0.440 | 0.425 | 0.410 | 0.396 | 0.381 | 0.366 |
| **0.6_** | 0.352 | 0.338 | 0.323 | 0.309 | 0.295 | 0.282 | 0.268 | 0.255 | 0.242 | 0.229 |
| **0.7_** | 0.216 | 0.204 | 0.191 | 0.179 | 0.168 | 0.156 | 0.145 | 0.134 | 0.124 | 0.114 |
| **0.8_** | 0.104 | 0.095 | 0.086 | 0.077 | 0.069 | 0.061 | 0.053 | 0.046 | 0.040 | 0.034 |
| **0.9_** | 0.028 | 0.023 | 0.018 | 0.014 | 0.010 | 0.007 | 0.005 | 0.003 | 0.001 | 0.000 |

## Design assumptions for SWG ASSY® VG screws as reinforcement

*Table 4: buckling resistance * of one screw considering an angle between screw axis to wood grain of α = 90°*

# Contact MTC Solutions for the buckling resistance of ASSY Screws.

# Support@MTCSolutions.com

*Table 5: timber densities*

| Timber densities | | |
|---|---|---|
| **Visually graded lumber** | **Glue-laminated timber** | **Mean oven dry relative density** |
| Northern Species | | **0.35** |
| Spruce-Pine-Fir | | **0.42** |
| | Spruce-Pine-Fir | **0.44** |
| Hem-Fir | Hem-Fir | **0.46** |
| Douglas-Fir-Larch<br>D-Fir-L | Douglas-Fir-Larch<br>D-Fir-L | **0.49** |
| PSL, LVL, LSL | PSL, LVL, LSL | **0.5** |

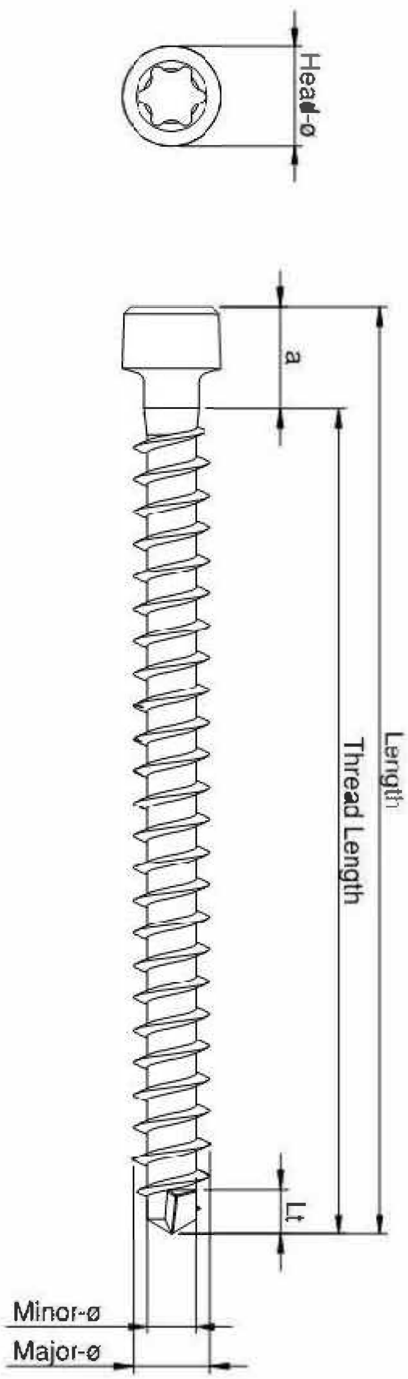
*Table 6: Minimum spacing or distance for SWG ASSY® VG screws*

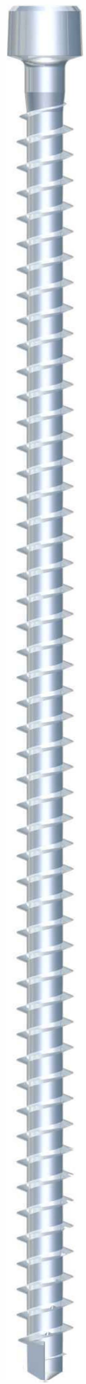
| SWG ASSY® VG screws loaded axially | |
|---|---|
| Minimum spacing or distance *[12]* | (D = outside thread diameter) |
| **$S_P$**<br>**Spacing parallel to grain** | 5D<br>(7.5D in D-Fir-L) |
| **$S_Q$**<br>**Spacing perpendicular to grain** | 2.5D |
| **$a_L$**<br>**end distance** | 5D<br>(7.5D in D-Fir-L) |
| **$e_L$**<br>**edge distance** | 3D |

## SWG ASSY® VG Cyl. (full thread)

*Table 7: SWG ASSY® VG Cyl screw specifications*

| Major Ø | Length | Thread Length | $L_t$ | Head Ø | Minor Ø | Bit |
|---|---|---|---|---|---|---|
| | | mm | | | | |
| 6 | **70** | 63 | 6 | 8 | 3.8 | AW 30 |
| | **80** | 73 | | | | |
| | **100** | 93 | | | | |
| | **120** | 113 | | | | |
| | **140** | 133 | | | | |
| | **160** | 153 | | | | |
| | **180** | 173 | | | | |
| | **200** | 193 | | | | |
| 8 | **160 to 300 in 20 mm increments** | 144 to 284 in 20 mm increments | 8 | 10 | 5 | AW 40 |
| | **330** | 314 | | | | |
| | **360** | 344 | | | | |
| | **380** | 364 | | | | |
| | **430** | 414 | | | | |
| | **480** | 464 | | | | |
| | **530** | 514 | | | | |
| | **580** | 564 | | | | |
| 10 | **140 to 280 in 20 mm increments** | 125 to 265 in 20 mm increments | 10 | 13.4 | 6.2 | AW 50 |
| | **300** | 280 | | | | |
| | **320 to 400 in 20 mm increments** | 305 to 380 in 20 mm increments | | | | |
| | **430** | 415 | | | | |
| | **480** | 456 | | | | |
| | **530** | 506 | | | | |
| | **580** | 556 | | | | |
| | **and longer** | and longer | | | | |



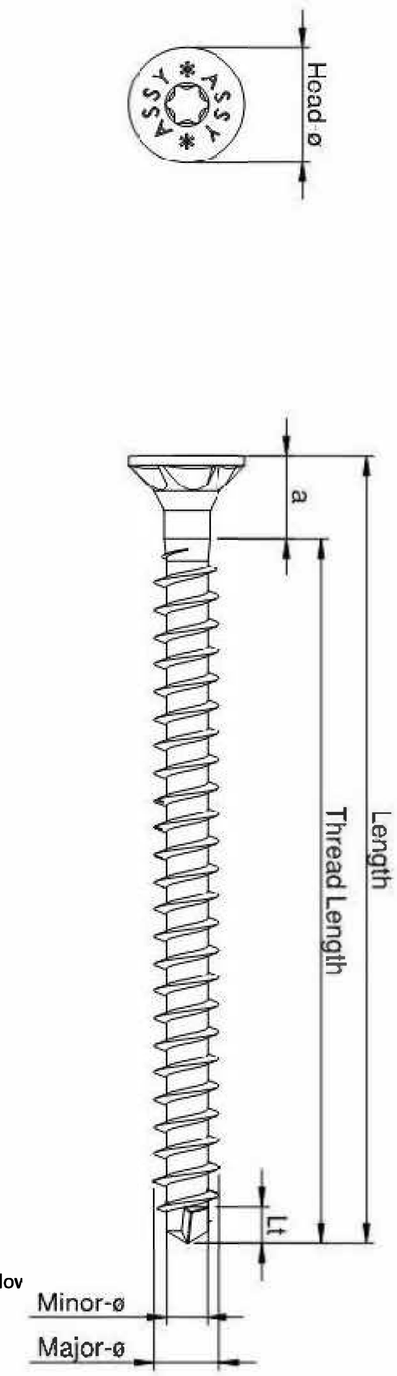
*Note:* values listed in the table above are average measurements between upper and lower tolerance boundary

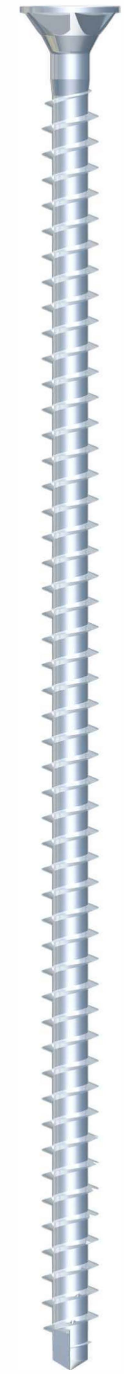
## SWG ASSY® VG CSK (full thread)

*Table 8: SWG ASSY® VG CSK screw specifications*

| Major ø | Length | Thread Length | $L_t$ | Head ø | Minor ø | Bit |
|---|---|---|---|---|---|---|
| mm | | | | | | |
| 8 | 120 | 103 | 8 | 14.8 | 5 | AW 40 |
| | 140 | 123 | | | | |
| | 160 | 143 | | | | |
| | 180 | 163 | | | | |
| | 200 | 183 | | | | |
| | 220 | 203 | | | | |
| | 240 | 223 | | | | |
| | 260 | 243 | | | | |
| | 280 | 263 | | | | |
| | 300 | 283 | | | | |
| 10 | 140 to 400 in 20 mm increments | 125 to 385 in 20 mm increments | 10 | 19.6 | 6.2 | AW 50 |
| | 430 | 415 | | | | |
| | 480 | 465 | | | | |
| | 530 | 512 | | | | |
| | 580 | 562 | | | | |
| | 650 to 800 in 50 mm increments | 632 to 782 in 50 mm increments | | | | |
| 12 | 220 | 205 | 12 | 22.1 | 7.1 | AW 50 |
| | 380 | 365 | | | | |
| | 480 | 465 | | | | |
| | 600 | 585 | | | | |

*Note:* values listed in the table above are average measurements between upper and lov tolerance boundary



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[1] CSA 086-09

[2] European Technical Approval ETA-11/0190: *A.3.2.2 Notched beam supports*

[3] European Technical Approval ETA-11/0190: *A.3.2.1 Connection forces at an angle to the grain*

[4] Eurocode 5—DIN EN 1995-1-1/NA:2010-12: *NA.6.8.4*

[5] Eurocode 5—DIN EN 1995-1-1/NA:2010-12: *NA.6.7 (NA.4)*

[6] Eurocode 5—DIN EN 1995-1-1:2010-12: *6.4.3 (7) & (8) Double tapered, curved and pitched cambered beams*

[7] Eurocode 5—DIN EN 1995-1-1/NA:2010-12: *NA.6.8.6*

[8] H.J Blass, J. Ehlbeck, H. Kreuzinger, G. Steck, *Erlaeuterungen zu DIN 1052:2004-08,* DGfH Innovations– und Service GmbH, Munich, 2004, 1. edition*, p.149*

[9] Eurocode 5—DIN EN 1995-1-1:2010-12: *6.1.5(1)*

[10] European Technical Approval ETA-11/0190: *Annex 2 Compression reinforcement perpendicular to the grain*

[11] Eurocode 5—DIN EN 1995-1-1:2010-12: *B.2 Effective bending stiffness*

[12] CCMC report 'CCMC 13677-R'

[13] Eurocode 5—DIN EN 1995-1-1:2010-12: *8.7.2(8) Axially loaded screws*

[14] DIN 1052-2004: *G.1 Slip modulus for slender fasteners*

[15] European Technical Approval ETA-11/0190: *A.1.3 Axially loaded screws*

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[17] European Technical Approval ETA-11/0190: *A.1.3.3 Compressive capacity*

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