MyTiCon Timber Connectors White Paper

MyTiCon Timber Connectors

Full thread SWG ASSY® Screws as Reinforcement

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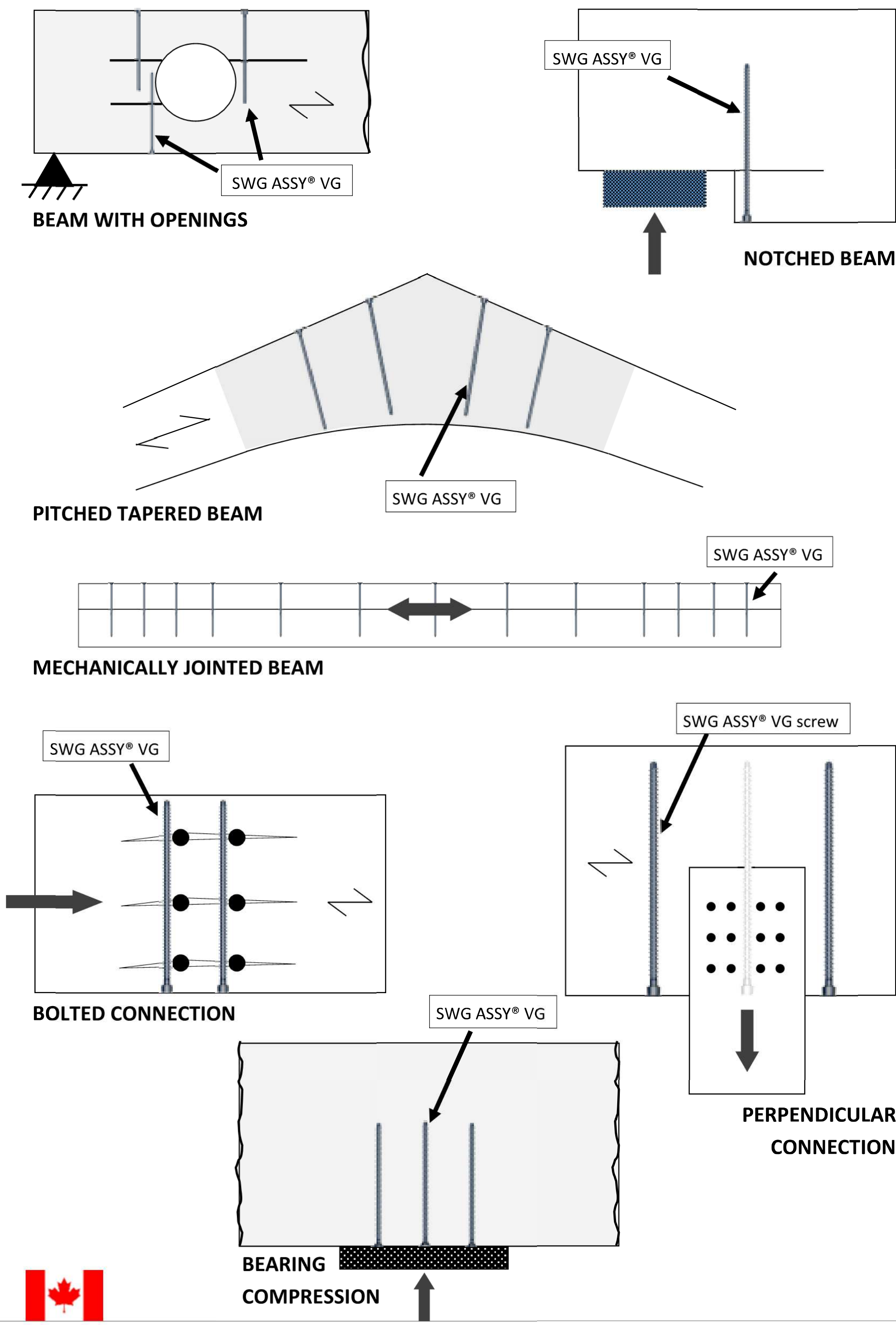

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Conditions of use and requirements as reinforcement perpendicular to the grain

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°.

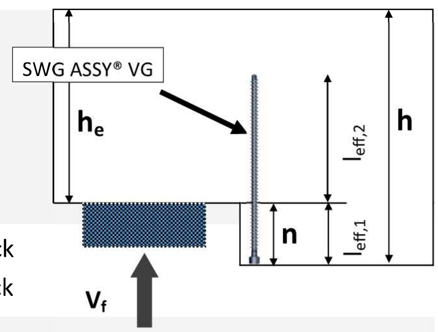
The provided design proposals are only applicable to the following timber species:

- 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)

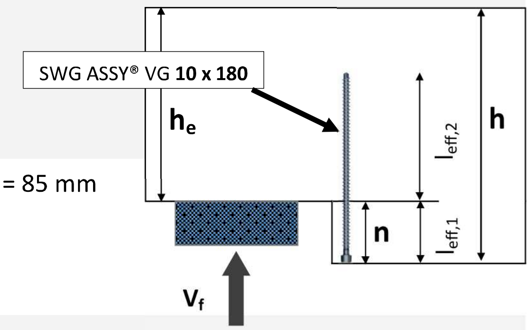
Notched beam reinforcement

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 **h** = beam depth **n** = notch depth $\mathbf{h_e}$ = distance from potential crack to the edge 
Effective thread length	$\mathbf{l_{eff,1}}$ = threaded length below potential crack $\mathbf{l_{eff,2}}$ = threaded length above potential crack
Longitudinal shear resistance [1]	$\mathbf{F_v} = f_v\,(K_D K_H K_{Sv} K_T)$ [N/mm²]
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] *(k_α values for standard α ratios are calculated in table 2)*	$\boldsymbol{\alpha} = (h_e / h)$ $\mathbf{k_\alpha} = 1.3 * [3 * (1-\alpha)^2 - 2 * (1-\alpha)^3]$
Tensile design force [2] to be transmitted by the reinforcing SWG ASSY® VG screws	$\mathbf{V_{r,t,90} = k_\alpha * V_f}$
boundary conditions for screw design withdrawal resistance [12]	<u>effective screw length</u>: $\mathbf{l_{eff} = \min\{l_{eff,1}\,;\,l_{eff,2}\}}$ <u>minimum penetration depth:</u> $\mathbf{p_{min} = 4 * D}$ (outside thread diameter) $\leq \mathbf{l_{eff}}$ (smaller penetration can not be taken into account for beam reinforcement)
Withdrawal resistance of one SWG ASSY® VG screw (refer to table 1)	$\mathbf{P'_{rw,\alpha}} = \min \begin{cases} \textbf{withdrawal resistance } [kN/20\,mm] * l_{eff} \\ \textbf{tensile resistance} \end{cases}$
Required number of reinforcing screws [1]	$\mathbf{n_{screws}} = \sqrt[0.9]{(V_{r,t,90} / P'_{rw,\alpha})}$

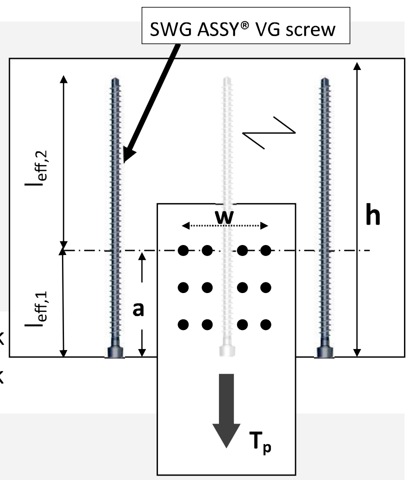
<u>*Note:*</u> [1] considering an effective number of screws $n_{eff} = n^{0.9}$ as per [13]
A minimum of 2 screws shall be used whereas only one may be used when minimum penetration depth below and above potential crack is 20*D (=outer thread screw diameter). Required spacing, end and edge distances 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”) **h** = 456 mm (18”) **n** = 100 mm (4”) h_e = 456—100 = 356 mm 
Effective thread length	$l_{eff,1}$ = 100—15 (unthreaded head) = 85 mm $l_{eff,2}$ = l_{screw} — n — l_{tip} (=D) = = 180 —100 – 10 = 70
Longitudinal shear resistance	F_v = 2 *1 = 2 N/mm^2
Maximum shear resistance [1]	$K_N = (1-100/456)^2 = 0.61$ A_g = 215 *456 = 98,040 mm^2 $V_{r,max}$ = 0.9 *2 *2/3 *98,040 *0.61 = 71.7 kN
Existing bearing reaction shear force	V_f = 100 kN
CONDITION	**100 > 71.7 —> REINFORCEMENT IS REQUIRED**
Factors [2] *(k_α values for standard α ratios are calculated in table 2)*	**α** = (356 /456) = 0.78 k_α = 0.161 (table 2)
Tensile design force [2] to be transmitted by the reinforcing SWG ASSY® VG screws	$V_{r,t,90}$ = 0.161 * 100 = 16.1 kN
boundary conditions for screw design withdrawal resistance [12]	effective screw length: l_{eff} = min {70 ; 85} = 70 mm minimum penetration depth : p_{min} = 4 * 10 = 40 < 70 ✓
Withdrawal resistance of one SWG ASSY® VG screw (refer to table 1)	$P'_{rw,\alpha}$ = min { 2.00 kN/20 mm * 70 mm = **7 kN** ; 19.2 kN
Required number of reinforcing screws [1]	$n_{screws} = \sqrt[0.9]{(16.1/7)}$ = 2.5 **—> 3 screws** of type SWG ASSY® VG CYL 10 x 180

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

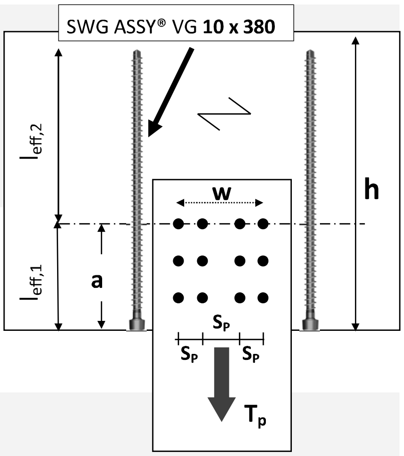
Perpendicular connection members with reinforcement

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] **h** = beam depth [mm] **a** = distance measured from the center of the upper row of fasteners (potential crack) to the loaded edge **w** = width of connection less the included fastener diameters 
Effective thread length	$l_{eff,1}$ = threaded length below potential crack $l_{eff,2}$ = 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] *(k_{tp} values for standard α ratios are calculated in table 3)*	$\alpha = (a / h)$ $k_{tp} = [1 - 3 * \alpha^2 + 2 * \alpha^3]$
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]	<u>effective screw length</u>: $l_{eff} = \min \{l_{eff,1} ; l_{eff,2}\}$ <u>minimum penetration depth:</u> $p_{min} = 4 * D$ (outside thread diameter) $\leq l_{eff}$ (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]	$n_{screws} = \sqrt[0.9]{(T_{r,tp,90} / P'_{rw,\alpha})}$

<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 PERPENDICULAR CONNECTION WITH REINFORCEMENT	
Example	GL 24f-E 130 x 456 mm (5-1/8 x 18“), $K_D = K_H = K_{Sf} = K_T = 1$, spacing between bolts (10 x 130 mm) is S_P = 152 mm (6”),
Geometry	**b** = 130 mm (5-1/8”) **h** = 456 mm (18”) **a** = 305 mm (12”) **w** = 3 * S_p—3 * d (= bolt diameter)
Effective thread length	$l_{eff,1}$ = 305—16 (unthreaded head) = 289 mm $l_{eff,2} = l_{screw}$ — a— l_{tip} (≙D) = = 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] *(k_{tp} values for standard α ratios are calculated in table 3)*	**α** = (305/456) = 0.67 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 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

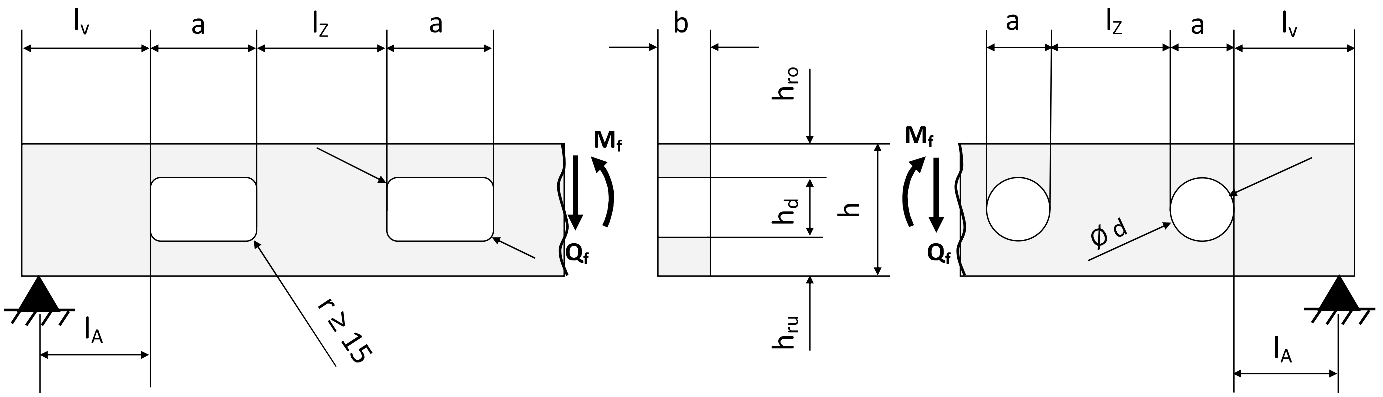
Reinforcing openings and penetrations

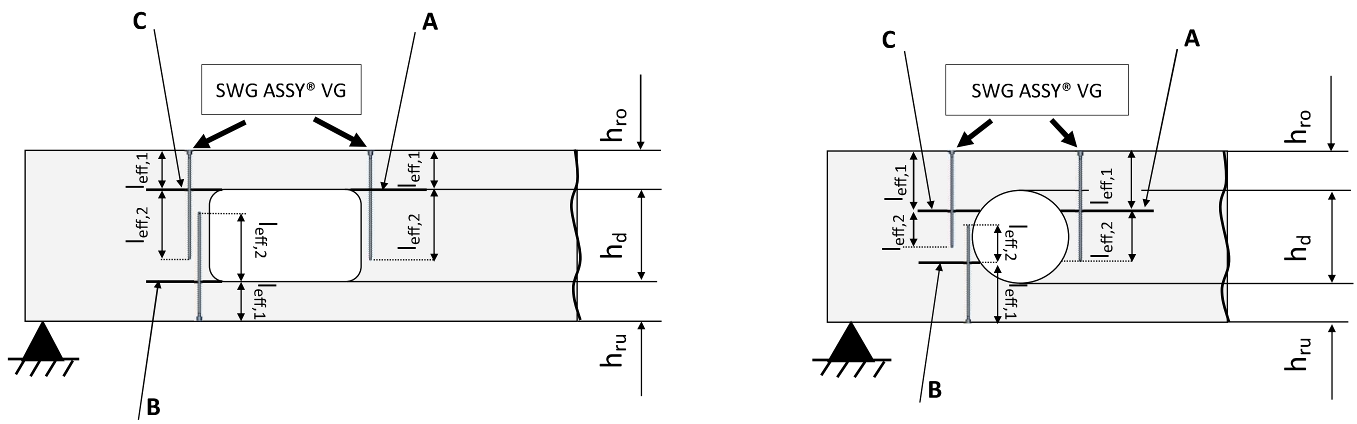
Holes greater d = 50 mm (2") may weaken the effective cross section so that shear and normal stress travel at the hole are impacted. Resulting forces perpendicular to grain may require reinforcement.

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 $\mathbf{F_{t,M,r} \leq F_{t,v,r}}$

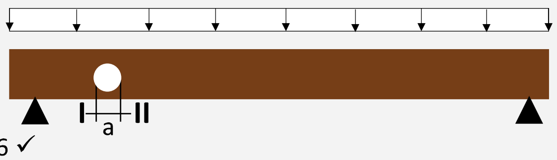
C **additional** potential crack to B on the **left side** of opening, if $\mathbf{F_{t,M,r} > F_{t,v,r}}$

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 **h** = beam depth **a** = length resp. diameter of the hole
Effective thread length	Rectangular hole: $l_{eff,1}$ = min {h_{ro} ; h_{ru}} less unthread head part $l_{eff,2}$ = remaining threaded length less tip length (tip length = outer thread diameter) Circular hole: $l_{eff,1}$ = min {h_{ro} + 0.15 *h_d ; h_{ru}+ 0.15 *h_d} less unthread part $l_{eff,2}$ = 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) Circular hole: $l_{t,90}$ = 0.353 *h_d + 0.5 *h $k_{t,90}$ = min{ $(450/h)^{0.5}$; 1}
Net tension resistance [5]	$T_{r,tp,max}$ = 0.5 *$l_{t,90}$ *b *$k_{t,90}$ * ϕ (=0.7) *F_{tp}
External load at section	Q_f , M_f
Reduced height [5]	Rectangular hole: h_r = min {h_{ro} ; h_{ru}} 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 {$l_{eff,1}$; $l_{eff,2}$} minimum penetration depth: p_{min} = 4 * D (outside thread diameter) ≤ l_{eff} (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.**

EXAMPLE REINFORCEMENT FOR BEAM WITH OPENINGS AND PENETRATIONS [1]	
Example	Single span beam: GL 24f-E 215 x 456 mm (8.5 x 18"), $K_D = K_H = K_{Sf} = K_T = 1$, hole size: a = 200 in the center of the beam depth screws: SWG ASSY® VG **10 x 280**
Geometry	**b** = 215 mm (8.5") **d** = 456 mm (18") **a** = h_d = 200 ≤ 456 ✓ h_{ro} = h_{ru} = (456— 200)/2 = 128 mm ≥ 0.25*456 ✓ 
Effective thread length with circular hole	$l_{eff,1}$ = 128 + 0.15 *200—15 = 143 $l_{eff,2}$ = 280—143—10 = 127
Tensile strength perpendicular to grain [1]	F_{tp} = 0.83 *1 [N/mm^2]
Design and reduction factors for circular hole	$l_{t,90}$ = 0.353 *200 + 0.5 *456 = 298.6 mm $k_{t,90}$ = min{ (450/456)$^{0.5}$; 1} = 0.993
Net tension resistance [5]	$T_{r,tp,max}$ = 0.5 *298.6 *215 *0.993 *0.7 *0.83 = 15.9 kN
Load at section I	$Q_{f,I}$ = 80 kN , $M_{f,I}$ = 100 kNm
Relative height with circular hole	h_r = 128 + 0.15 *200 = 158 mm
Design stress [5] at opening perpendicular-to-grain from shear	$F_{t,V,r}$ = (80 *200) / (4 *456) *[3—(200^2 /456^2)] = 24.6 kN
Design stress [5] at opening perpendicular-to-grain from bending	$F_{t,M,r}$ = 0.008 *(100 *10^3) / 158 = 5.1 kN
Resulting design stress [5] at opening perpendicular-to-grain	$F_{t,r}$ = 24.6 + 5.1 = 29.7 kN
CONDITION	29.7 ≥ 15.9 —> **REINFORCEMENT IS REQUIRED**
Tensile design force [5] to be transmitted by the reinforcing ASSY® VG screws	$F_{t,r}$ = 29.7 kN
boundary conditions for screw design withdrawal resistance [12]	effective screw length: l_{eff} = min {143 ; 127} = 127 mm minimum penetration depth: p_{min} = 4 * 10 = 40 < 127 ✓
Withdrawal resistance of one SWG ASSY® VG screw (refer to table 1)	$P'_{rw,\alpha}$ = **min** { 2.00 kN/20 mm * 127 mm = **12.7 kN** ; 19.2 kN }
Required number of reinforcing screws [2]	$n_{screws} = \sqrt[0.9]{(29.7 / 12.7)} = 2.57$ **—> 3 screws per side** of type SWG ASSY® VG CYL 10 x 280 **—>** see page 6 for screw arrangement

Note: [1] only valid if $F_{t,M,r} \leq F_{t,V,r}$

[2] considering an effective number of screws $n_{eff} = n^{0.9}$ as per [13]

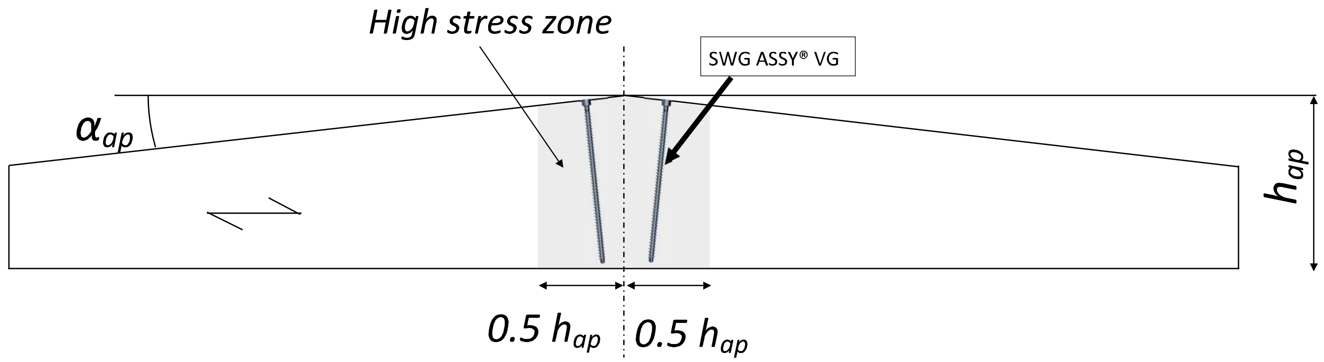
Screws to be driven in on each side of opening **sufficiently extending into the timber below and above opening**

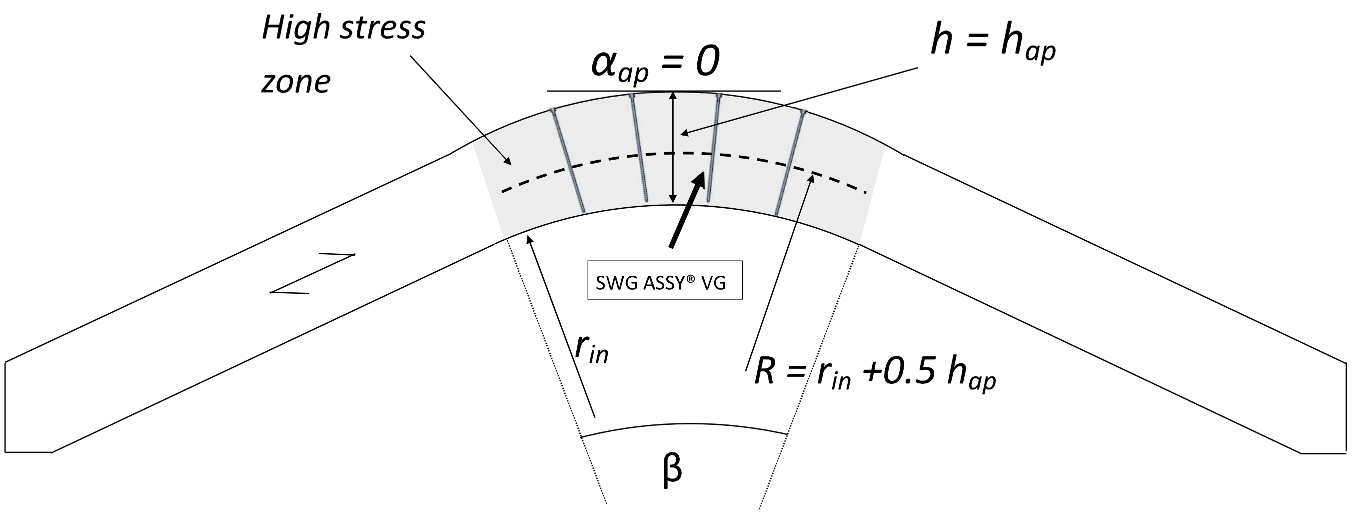
Required spacing, end and edge distances as per *table 6* to be followed.

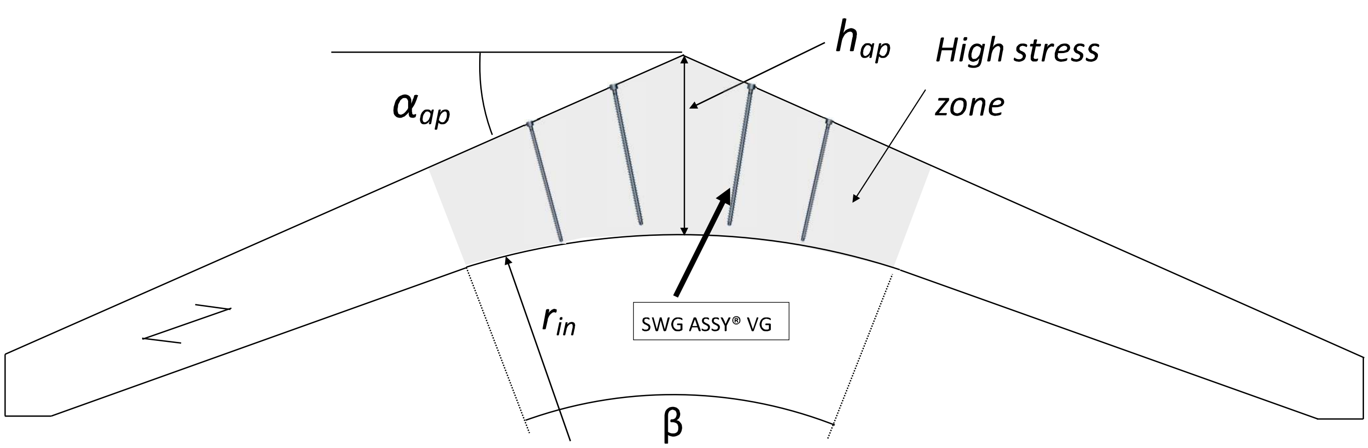
Reinforcing pitched tapered beams

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 **h** = beam depth h_{ap} = beam depth at the apex r_{in} = inner radius at the apex **r** = $r_{in} + 0.5\ h_{ap}$ (radius of curvature at centreline) α_{ap} = angle of the taper in the centre of the apex **β** = enclosed angle in radians
Effective thread length [7]	**Screws must penetrate the entire beam depth —> $l_{screw} \approx h$** $l_{eff,1}$ = half of the screw length less the unthreaded head part [mm] $l_{eff,2}$ = 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/mm^2]
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]	$k_6 = 0.25 - 1.5 * \tan \alpha_{ap} + 2.6 * \tan^2 \alpha_{ap}$ $k_7 = 2.1 * \tan \alpha_{ap} - 4 * \tan^2 \alpha_{ap}$ $k_p = 0.2 * \tan \alpha_{ap} + k_6 * (h_{ap} / r) + k_7 * (h_{ap} / r)^2$
Greatest tensile stress [6] perpendicular-to -grain at the apex due to bending moment	$\sigma_{r,t,90} = k_p * (6 * M_{r,ap}) / (b * h_{ap}^2)$ [N/mm^2]
Spacing of fasteners [7]	$250\ mm \leq a_1 \leq 0.75 * h_{ap}$
Tensile design force [7] to be transmitted by the reinforcing ASSY® VG screws	$F_{t,r} = \sigma_{r,t,90} * b * a_1$
boundary conditions for screw design with-drawal resistance [12]	<u>effective screw length</u>: $l_{eff} = \min \{l_{eff,1}\ ;\ l_{eff,2}\}$ <u>minimum penetration depth:</u> $p_{min} = 4 * D$ (outside thread diameter) $\leq l_{eff}$ (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]	$n_{screws} = \sqrt[0.9]{(F_{t,r} / P'_{rw,\alpha})}$

<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.

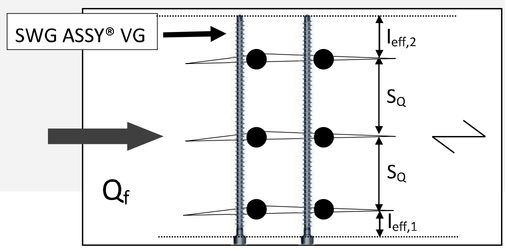
EXAMPLE PITCHED TAPERED BEAM REINFORCEMENT	
Example	Pitched double-tapered beam: GL 24f-E 130 x 456 mm (5-1/8 x 18")
Geometry	**b** = 130 mm (5-1/8") **h** = 456 mm (18") $\mathbf{h_{ap}}$ = 813 mm (32") $\mathbf{r_{in}}$ = 2800 mm **r** = 2800 + 0.5 *813 = 3206.5 mm $\boldsymbol{\alpha_{ap}}$ = 39° **β** = 51.3° * π/180°
Effective thread length [7]	$\mathbf{l_{screw}}$ ≈ h = 456 mm —> SWG ASSY® VG Cyl 10x430 $\mathbf{l_{eff,1}}$ = 215—15 = 200 mm $\mathbf{l_{eff,2}}$ = 215—10 = 205 mm
Tensile strength perpendicular to grain [1]	$\mathbf{F_{tp}}$ = 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 $\mathbf{M_{rt}}$ = 0.9 *0.83 *(130 *813^2 /6) *0.7 *7.0 = **<u>52.4 kNm</u>** **(**$\mathbf{M_{rt}}$ = 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	$\mathbf{M_{r,ap}}$ = 70 kNm
CONDITION	70 ≥ 52.4 **—> REINFORCEMENT IS REQUIRED**
Factors [6]	$\mathbf{k_6}$ = 0.25 — 1.5 *tan 39 + 2.6 *tan^2 39 = 0.74 $\mathbf{k_7}$ = 2.1 *tan 39 — 4 *tan^2 39 = - 0.92 $\mathbf{k_p}$ = 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	$\boldsymbol{\sigma_{r,t,90}}$ = 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	$\mathbf{F_{t,r}}$ **=** 1.42 *130 *355 = 65.5 kN
boundary conditions for screw design with-drawal resistance [12]	<u>effective screw length</u>: $\mathbf{l_{eff}}$ = min {200 ; 205} = 200 mm <u>minimum penetration depth:</u> $\mathbf{p_{min}}$ = 4 *10 = 40 < 200 ✓
Withdrawal resistance of one SWG ASSY® VG screw (refer to table 1)	$\mathbf{P'_{rw,\alpha}}$ = **min** { 2.00 kN/20 mm * 200 mm = 20 kN ; **<u>19.2 kN</u>** }
Required number of reinforcing screws [1]	$\mathbf{n_{screws}} = \sqrt[0.9]{(65.5 / 19.2)}$ = 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

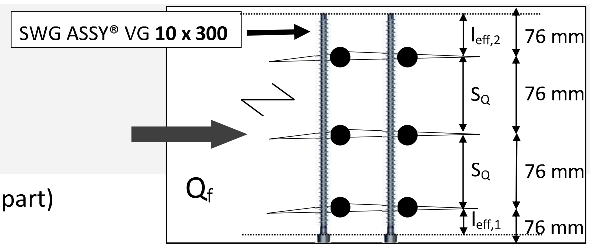
Bolted connections with multiple bolts per row may fail brittle due to splitting. Design codes reduce the effective number of bolts by at least 2/3 to reduce brittle failure through splitting.

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 **d** = beam depth $\mathbf{S_Q}$ = spacing between bolts perpendicular to grain $\mathbf{e_L}$ = minimum bolt edge distance 
Effective thread length	$\mathbf{l_{eff,1}}$ = threaded length below lower potential crack $\mathbf{l_{eff,2}}$ = 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 $\mathbf{n_{sp}}$ = 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]	<u>effective screw length</u>: $\mathbf{l_{eff} = min \{l_{eff,1} ; l_{eff,2}\}}$ <u>minimum penetration depth:</u> $\mathbf{p_{min} = 4 * D}$ (outside thread diameter) $\leq \mathbf{l_{eff}}$ (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]	$\mathbf{n_{screws} = {}^{0.9}\sqrt{(F_{r,t,90} / P'_{rw,\alpha})}}$

<u>*Note:*</u> [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") **d** = 304 mm (12") $\mathbf{S_Q}$ = 76 mm (3") $\mathbf{e_L}$ = 76 mm (3")
Effective thread length	$\mathbf{l_{eff,1}}$ = 76 — 15 (unthread part) = 61 mm $\mathbf{l_{eff,2}}$ = 300—2*76—76—10 (= tip length) = 62 mm

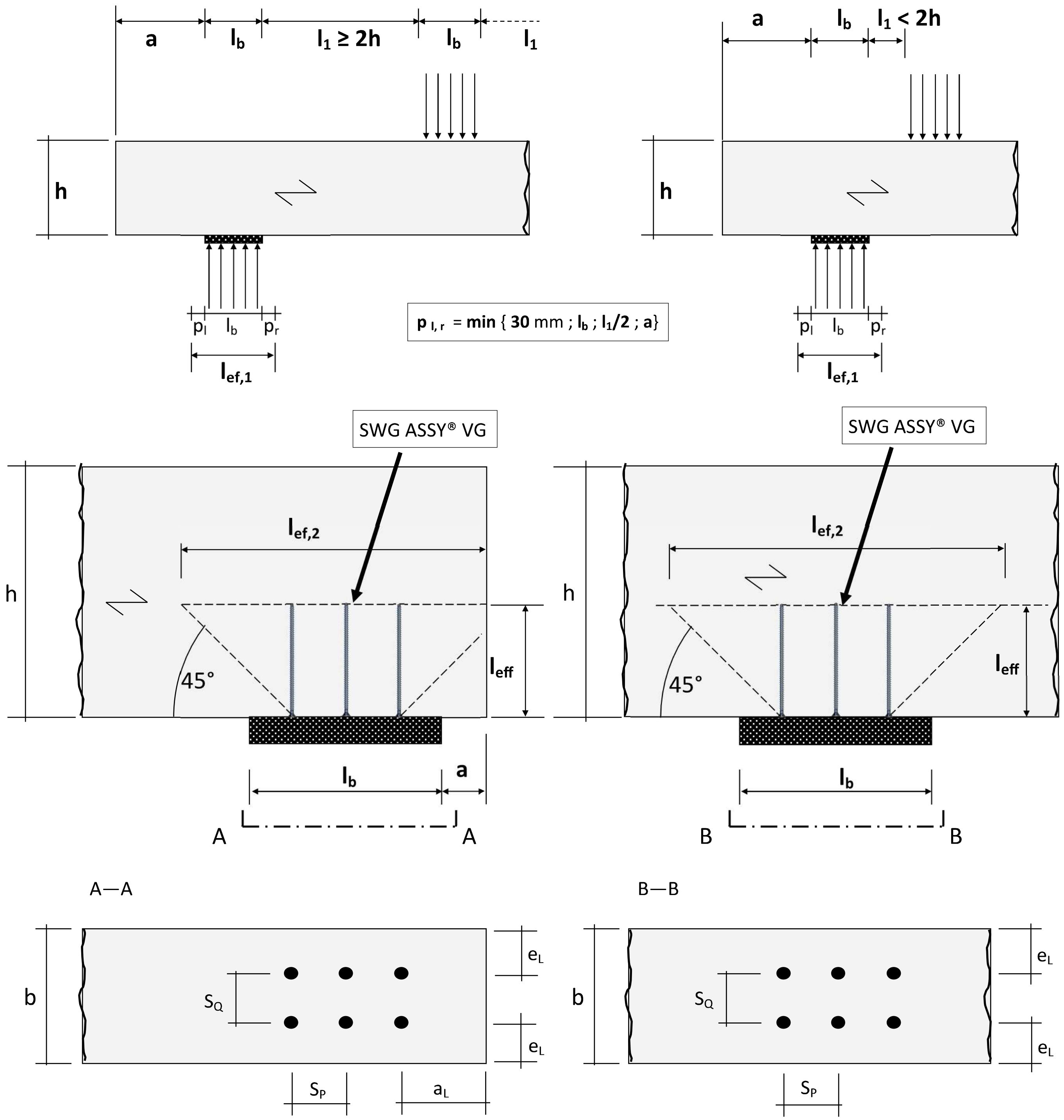


Connection parameters	$\mathbf{P_r}$ = 5.5 kN
	$\mathbf{n_{sp}}$ = 1
Tensile design force [8] per bolt perpendicular-to-grain to be transmitted by the reinforcing ASSY® VG screws	$\mathbf{F_{r,t,90}}$ = 1 * 0.3 * 5.5 = 3.3 kN
boundary conditions for screw design withdrawal resistance [12]	effective screw length: $\mathbf{l_{eff}}$ **=** min {61 ; 62} = 61 mm
	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.

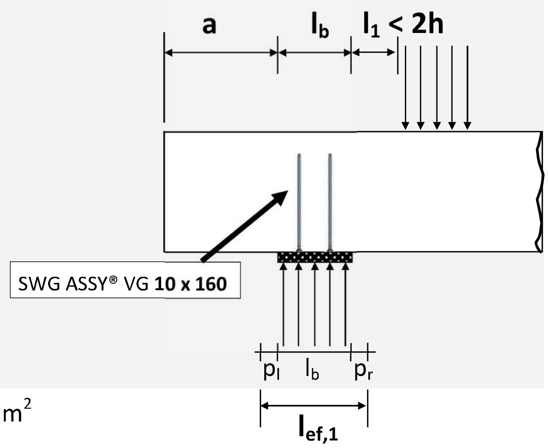
Compression reinforcement perpendicular to grain

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 **h** = beam depth **a** = distance from compressed area to beam end l_b = bearing length of support l_{eff} = threaded length less one outer thread diameter for the tip length l_1 = length between supports or incoming concentrated load n_0 = number of reinforcing screws arranged in a row parallel to grain S_P = spacing of reinforcing screws in a plane parallel to grain a_L = end distance of centre of gravity of threaded part in timber member e_L = edge distance of centre of gravity of threaded part in timber member
Strength in compression perpendicular to grain [1]	$F_{cp} = \phi * f_{cp} * (K_D K_{Scp} K_T K_B K_{Zcp})$
Factored compressive resistance perpendicular to grain [1]	Q_r
Compressive design force	Q_f
CONDITION	**IF** $Q_f \geq Q_r$ **REINFORCEMENT IS REQUIRED**
Effective length of distribution $l_{ef,1}$ [9]	Effective bearing length (**l**eft, **r**ight): $p_{l,r}$ = **min** { **30** mm ; l_b ; $l_1/2$; **a**} $l_{ef,1} = l_b + p_l + p_r$
Compressive reduction factor for discrete supports [9]	$l_1 < 2h$: $k_{c,90} = 1.00$ $l_1 \geq 2h$: $k_{c,90} = 1.75$ (glulam with $l_b \leq 400$ mm); $k_{c,90} = 1.50$ (softwood solid sawn); $k_{c,90} = 1.00$ (hardwood)
Design resistance [10] perpendicular-to-grain of a contact area	$R_{cb,90,d} = k_{c,90} * b * l_{ef,1} * F_{cp}$
boundary conditions for screw design compression resistance [12]	Effective thread penetration length: l_{eff} minimum penetration depth: p_{min} **= 4 * D** (outside thread diameter) (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)	$P'_{rw,\alpha}$ = min { **withdrawal resistance** [kN/20 mm] * l_{eff} *(refer to table 1)*; **tensile resistance** *(refer to table 1)*; **buckling resistance of the screw** *(refer to table 4)* }
Required number [1] of reinforcing screws [10]	$n_{screws} = {}^{0.9}\sqrt{([Q_f - R_{cb,90,d}] / P'_{rw,\alpha})}$
Effective contact length in the plane of the screw tips $l_{ef,2}$ [10]	End supports: $l_{ef,2} = \{l_{eff} + (n_0 - 1) * S_p + \min(l_{eff} ; a_L)\}$ intermediate supports: $l_{ef,2} = \{2 * l_{eff} + (n_0 - 1) * S_p\}$
***CONDITION** [10]*	$R_{c,tip,90,d} = b * l_{ef,2} * F_{cp} \geq Q_f$ **—>** 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

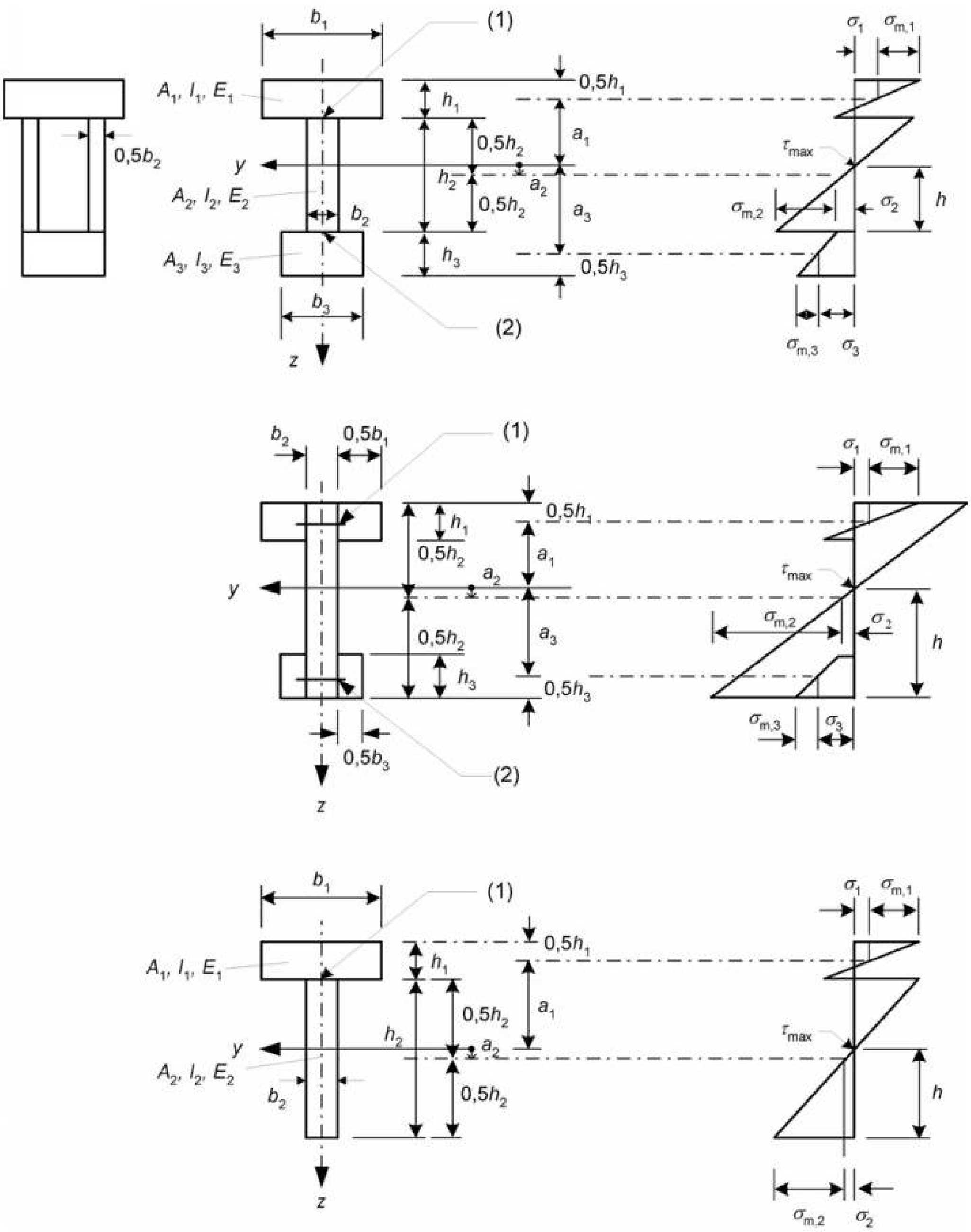
EXAMPLE COMPRESSION REINFORCEMENT PERPENDICULAR TO GRAIN	
Example	GL 24f-E 215 x 456 mm (8.5 x 18”) with an end support potential reinforcement: SWG ASSY® VG CSK **10 x 160** mm
Geometry	**b** = 215 mm (8.5”) **h** = 456 mm (18”) **a** = 81 mm l_b = 100 mm l_{eff} = 160—10 = 150 mm l_1 = 750 mm n_0 = 2 S_P = 76 mm (3”) a_L = 114 mm (4-1/2”) e_L = 76 mm (3”) 
Strength in compression perpendicular to grain [1]	F_{cp} = 0.8 * 7 *1.0 = 5.6 N/mm^2
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 (**l**eft, **r**ight): p_l = min { 30 ; 100 ; 750/2; 81} = 30 mm p_r = min { 30 ; 100 ; 750/2} = 30 mm $l_{ef,1}$ = 100 + 30 + 30 = 160 mm
Compressive reduction factor for discrete supports [9]	750 < 2* 456 = 912 mm $k_{c,90}$ = 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 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]	$n_{screws} = \sqrt[0.9]{[220 - 192.6]/15} = 1.95$ —> **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

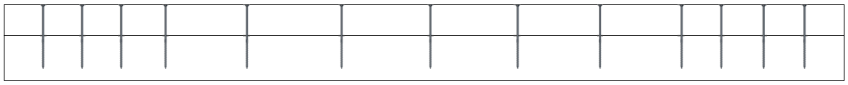
Picture 1: mechanically jointed beams according to [11]

Effective section properties

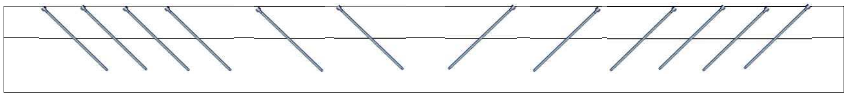
EXAMPLE MECHANICALLY JOINTED BEAM		
Example	GL 24f-E 130 x 456 mm (5-1/8 x 18") single span beam of 5.5 m (18') length with uniform design load of 11.7 kN/m (800 lbf/ft) adding 3 lamellas of 38 mm (1-1/2") of equal grade	
Geometry	**b** $= 130$ mm $= b_1 = b_2$	beam width
	$\mathbf{h_1}$ $= 3 * 38 = 114$ 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
	$E_{ser} = E_{mean}$	Serviceability modulus of elasticity
	$E_U = E_{mean}/\gamma_m = 12{,}800/1.3 =$ $= 9846$ 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

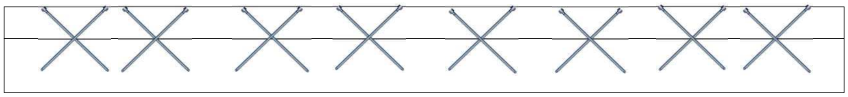
Version 1: *partial thread SWG ASSY® Screws inserted perpendicular*



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**: t_1 = 114 mm — embedment in added member t_2 = 240—114—10 = 116 mm — penetration in original beam less one diameter for the tip length l_p **= min** {t_1 ; t_2} = 114 mm minimum penetration depth: p_{min} **= 4 * D** (outside thread diameter) = 4*10 = 40 < 114 ✓ (smaller penetration can not be taken into account for beam reinforcement)
Slip modulus in shear plane [14] *(ρ_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 Ultimate state: K_U = 2/3 *K_{ser}/γ_m = 2/3 *2107/1.3 = 831 N/mm **Ultimate state design**: $K_1 = K_U$ = **831** N/mm (K_3 = 0)
Effectivity of added member eccentricity to inertia [11] (γ_3 = 0)	γ_1 = **1/(1 + π^2 * E_1* A_1*s/(K_1 * l_{eff}^2))** = 1/(1+ π^2 * 9,846* 14,820*152.5/(831 * $5,500^2$) = 0.1027
Effectivity of original beam eccentricity to inertia [11]	γ_2 = 1
*Distance of single member **i** centre of gravity to neutral stress axis [11]* *(a_3 = 0)*	a_2 **= γ_1*E_1*A_1*(h_1 + h_2)/ [2*(γ_1*E_1*A_1 + 1 *E_2*A_2 + γ_3*E_3*A_3)]** = 0.1027*9,846*14,820*(114 + 456)]/ [2*(0.1027*9,846*14,820 + 9,846*59,280)] = 7.13 mm a_1 = **(h_1 + h_2) /2— a_2** = (114 + 456)/2— 7.13 = 277.87 mm
Effective moment of inertia [11]	I_{eff} **= (I_1 + γ_1 *A_1 *a_1^2) + (I_2 + 1 *A_2 *a_2^2) + (I_3 + γ_3 *A_3 *a_3^2)** = (16,050,060 + 0.1027 *14,820 *277.87^2) + (1,027,203,840 + 1 *59,280 *7.13^2) = 1,163,784,856 mm^4 **$(EI)_{eff}$ = (E_1 *I_1 + E_1 *γ_1 *A_1 *a_1^2) + (E_2 *I_2 + E_2 *1 *A_2 *a_2^2) + (E_3 *I_3 + E_3 *γ_3 *A_3 *a_3^2)** = 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) = 2.62 kN (mode g with 114 mm penetration)
Lateral design force** [11] to be transmitted by **one vertical inserted ASSY® screw** [1]* ***(α = 90°) —> Version 1	$V_{v,1}$ **= V *(E_1 *γ_1 *A_1 *a_1*s) / $(EI)_{eff}$** = 32.2 *(9,846 *0.1027 *14,820 *277.87 *152.5) /11,458,625,690,000 = 1.78 kN per screw $V_{v,3}$ **= V *(E_3 *γ_3 *A_3 *a_3*s) / $(EI)_{eff}$** = 0
$P_{r,v}$ = 2.62 kN ≥ $V_{v,1}$ = 1.78 kN ✓	

<u>Note:</u> [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**: $l_{eff,1}$ = √2 *114—15 = 146 mm — thread penetration in added member less un-threaded head $l_{eff,2}$ = 330—√2 *114—8 = 160 mm — thread penetration in original beam less one diameter for the tip length l_p **= min** {$l_{eff,1}$; $l_{eff,2}$} = 146 mm minimum penetration depth: p_{min} **= 4 * D** (outside thread diameter) = 4*8 = 32 < 146 ✓ (smaller penetration can not be taken into account for beam reinforcement)
Slip modulus [15,16] *(ser: serviceability design* *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 Ultimate state: $K_U = 2/3 * K_{ser}/\gamma_m = 2266$ N/mm Slip modulus in shear plane (**ultimate state design**) $K_1 = K_U * \cos^2\alpha = 1185 * (\cos 45)^2 = \underline{\mathbf{1133}}$ N/mm
Effectivity of added member eccentricity to inertia [11] ($\gamma_3 = 0$)	$\gamma_1 = 1/(1 + \pi^2 * E_1 * A_1 * s/(K_1 * l_{eff}^2))$ $= 1/(1+ \pi^2 * 9,846 * 14,820*152.5/(1133 * 5,500^2)) = 0.1350$
Effectivity of original beam eccentricity to inertia [11]	$\gamma_2 = 1$
Distance of single member **i** *centre of gravity to neutral stress axis [11]* *($a_3 = 0$)*	$a_2 = [\gamma_1 * E_1 * A_1 * (h_1 + h_2)]/[2*(\gamma_1 * E_1 * A_1 + 1 * E_2 * A_2 + \gamma_3 * E_3 * A_3)]$ $= [0.1350*9,846*14,820*(114 + 456)]/ [2*(0.1350*9,846*14,820 + 9,846*59,280)]$ $= 9.30$ mm $a_1 = (h_1 + h_2) /2 - a_2 = (114 + 456)/2 - 9.30 = 275.7$ mm
Effective moment of inertia [11]	$I_{eff} = (I_1 + \gamma_1 * A_1 * a_1^2) + (I_2 + 1 * A_2 * a_2^2) + (I_3 + \gamma_3 * A_3 * a_3^2)$ $= (16,050,060 + 0.1350 * 14,820 * 275.7^2) + (1,027,203,840 + 1 * 59,280 * 9.30^2)$ $= 1,200,455,215$ mm^4 $(EI)_{eff} = (E_1 * I_1 + E_1 * \gamma_1 * A_1 * a_1^2) + (E_2 * I_2 + E_2 * 1 * A_2 * a_2^2) + 0$ $= E * I_{eff} = 11,819,682,040,000$ 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] ***(α = 45°) —> Version 2*** *($V_{v,3} = V_{t,3} = 0$)*	$V_{v,1} = V * (E_1 * \gamma_1 * A_1 * a_1 * s) / (EI)_{eff}$ $= 32.2 * (9,846 * 0.1350 * 14,820 * 275.7 * 152.5) / 11,819,682,040,000$ = 2.26 kN per screw $V_{t,1} = V_{v,1} / (\cos\alpha) = 1.78 / \cos 45 = 3.19$ 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] ***—> Version 3***	$V_{t,1} = V_{v,1} / (2 * \cos\alpha) = 2.26 / (2*\cos 45) = 1.60$ 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: $n_{req} = \sqrt[0.9]{n_{per\,m}}$. 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_α for standard beam sizes and connections

Values for k_α 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°*

buckling resistance* $\kappa_c \cdot N_{pl,d}$ in [kN (lbf)] of one SWG ASSY® VG screw								
specific gravity SG	Outer thread diameter							
	mm , kN	inch, lbf	**mm , kN**	inch, lbf	**mm , kN**	inch, lbf	**mm , kN**	inch, lbf
	6	1/4	**8**	5/16	**10**	3/8	**12**	1/2
0.42	**6.10**	1370	**11.05**	2481	**16.56**	3720	**24.64**	5535
0.49	**6.30**	1416	**11.42**	2566	**17.07**	3835	**25.51**	5731
0.5	**6.33**	1422	**11.47**	2577	**17.13**	3849	**25.62**	5756

Note: * resistance according to [17] considering an angle between screw axis and wood grain direction of α = 90°

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 D-Fir-L	Douglas-Fir-Larch D-Fir-L	**0.49**
PSL, LVL, LSL	PSL, LVL, LSL	**0.5**

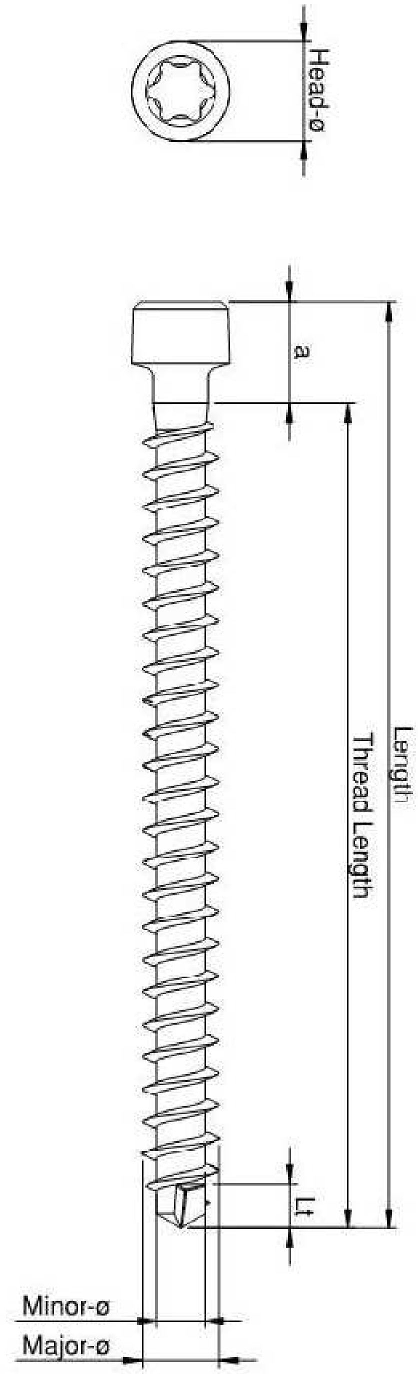
Table 6: Minimum spacing or distance for SWG ASSY® VG screws

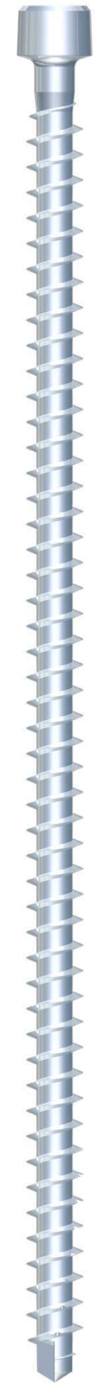
SWG ASSY® VG screws loaded axially	
Minimum spacing or distance *[12]*	(D = outside thread diameter)
S_P **Spacing parallel to grain**	5D (7.5D in D-Fir-L)
S_Q **Spacing perpendicular to grain**	2.5D
a_L **end distance**	5D (7.5D in D-Fir-L)
e_L **edge distance**	3D

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				





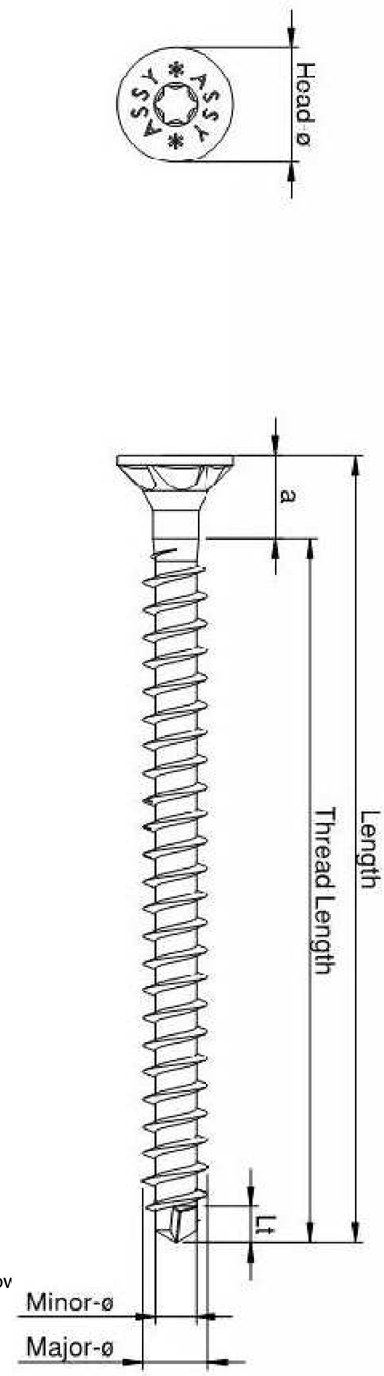
Note: values listed in the table above are average measurements between upper and lower tolerance boundary

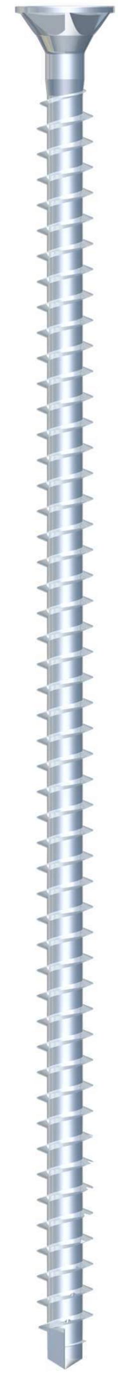
SWG ASSY® VG CSK (full thread)

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

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[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*

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

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

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[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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