# SCREWED CONNECTIONS

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1. GENERAL

Timber screws are well suited for steel-to-timber and panel-to-timber connections but they can also be used for timber-to-timber connections. Screw connections are generally designed for single shear connections. Screws are good at transmitting axial loads.

The nominal thickness $d$ means the outer thickness of the threaded part. This rule applies for screws where the inner threaded diameter of screw $d_i$ (the root diameter), should not be less than 60% and not more than 90% of the outer threaded diameter $d$ ($0.6 \, d \leq d_i \leq 0.9 \, d$).

Screws and glue do not have a co-operative action. Unless otherwise specified, screws should be driven to such a depth that the surface of the screw head is flush with the timber surface with a tolerance of $\pm 3$ mm. For inclined screwed connections the tolerance for angle is $\pm 5^\circ$.

Before installation of screws, ensure that the connecting members are positioned tightly together or the length of the unthreaded part is at least as much as the thickness of the connecting member.

1.1 LAG SCREW

A lag screw, in this guide, means a partly threaded screw, where the outer threaded diameter is equal to the shank diameter (nominal diameter $d$). When the smooth shank penetrates into the point side member by not less than $4 \, d$, the load-carrying capacity may be calculated using the nominal diameter $d$ of the smooth shank. For lag screws where the smooth shank point side penetration is less than $4 \, d$, the effective diameter value for screws is used, see 1.2.

1.2 SCREW

A screw, in this guide, means full of partly threaded screws, where the diameter of shank $d_s$ is not more than 80% of the outer threaded diameter (nominal diameter $d$) but at least $1.1 \, d_i$, where $d_i$ is the inner diameter (root diameter) of the threaded part.

$d_s \leq 0.8 \, d$ and $d_i \geq 1.1 \, d_i$  

(1)

The effective diameter for screws:

$d_{ef} = 1.1 \, d_i$  

(2)

If the screw fulfills the requirements of equation (3), the effective diameter $d_{ef}$ values presented in equation (4) may be used for Kerto-S and Kerto-Q.

$d_s \leq 0.8 \, d$ and $d_i \leq 0.7 \, d$  

(3)

$d_{ef} = \begin{cases} 0.66 \, d & \text{for load-carrying} \\ 0.80 \, d & \text{for spacing and edge distances} \end{cases}$  

(4)

where: $d$ is the outer threaded diameter (outer diameter of threads)

2. PRE-DRILLING

For lag screws in solid timber, glued laminated timber, panels and Kerto, with a diameter $d > 6$ mm, pre-drilling is required. The lead hole for the threaded portion should have a diameter $D = 0.6 \, d - 0.75 \, d$ in softwood and $0.7 \, d - 0.85 \, d$ in hardwood. The lead hole for the shank should have a diameter $D = d + 0.1$ and the same depth as the length of the shank. Timber should be pre-drilled also when $d < 6$ mm if the characteristic density of the timber $\rho_k$ is greater than 500 kg/m$^3$.

For screws, timber should be pre-drilled when: the characteristic density of the timber $\rho_k$ is greater than 500 kg/m$^3$, or the diameter $d$ of the screw exceeds 8 mm, or the diameter of the smooth shank $d_s$ exceeds 6 mm. The characteristic density of Kerto-S and Kerto-Q is 480 kg/m$^3$ and Kerto-T 410 kg/m$^3$. The diameter of pre-drilled holes for a non-self-drilling screw should be $D = 0.5 \, d - 0.7 \, d$ but not more than the inner threaded diameter $d_i$, where $d$ is the screw diameter.
Solid timber, glued laminated timber, flatwise Kerto-S and flatwise Kerto-T should be pre-drilled when the thickness $t$ of the timber member is smaller than:

$$
t = \max\left\{ \frac{7d_{ef}}{(13d_{ef} - 30) \cdot \rho_k} \right\} \text{[mm]} \quad (5)$$

where: $\rho_k$ is the characteristic timber density, in kg/m$^3$
$d_{ef}$ is the screw effective diameter, in mm

The minimum thickness of flatwise Kerto-Q is not limited for screws without pre-drilled holes. 7

Edgewise Kerto-LVL should be pre-drilled when the thickness $t$ of the timber member is smaller than equation (6), for other screwed connections the EN 1995-1-1:2004 clause 8.3.1.2(7) may be neglected.

$$
t = \max\left\{ \frac{14d_{ef}}{(13d_{ef} - 30) \cdot \rho_k} \right\} \text{[mm]} \quad (6)$$

where: $\rho_k$ is the characteristic timber density, in kg/m$^3$
$d_{ef}$ is the screw effective diameter, in mm

3. Material Properties

The simplified design method presented in this guide is valid for the screws manufactured with nominal diameter $3.8 \text{ mm} \leq d \leq 24 \text{ mm}$ and with minimum tensile strength $f_{u,k} \geq 500 \text{ N/mm}^2$ or with a characteristic value for yield moment $M_{y,k} \geq 150 \text{ d}_{ef}^2$. The following details are needed from screw manufacturer for design:

- The characteristic point-side withdrawal strength $f_{ax,k} \text{ [N/mm}^2\text{]}$ together with the characteristic density $\rho_k \text{ [kg/m}^3\text{]}$ of the timber used or the type of wood based product used
- The characteristic value for the yield moment $M_{y,k} \text{ [Nmm]}$ together with the characteristic density $\rho_k \text{ [kg/m}^3\text{]}$ of the timber used or the type of wood based product used
- The characteristic tensile capacity $f_{tens,k} \text{ [kN]}$
- The characteristic head-side pull-through strength $f_{head,k} \text{ [N/mm}^2\text{]}$ togethers with the characteristic density $\rho_k \text{ [kg/m}^3\text{]}$ of the timber used or the type of wood based product used
- The characteristic smooth shank diameter $d_s \text{ [mm]}$ and for partly threaded screws the length of the threaded part $l_g \text{ [mm]}$.

Steel plates need to be pre-drilled structural steel or austenitic stainless steel.

Screws and steel plates should, where necessary, either be inherently corrosion-resistant or be protected against corrosion.

| Table 1: The minimum specifications for material protection against corrosion for fasteners. Electroplated zinc coating Fe/Zn classes are according to ISO 2081 and hot-dip coating Z classes according to EN 10346. Stainless steel according to EN 10088-1 (grades 1.4401, 1.4301 and 1.4310). |
|---------------------------------|---------------------------------|---------------------------------|
| FASTENER                        | SERVICE CLASS |
|---------------------------------|------|------|------|
| Screws with $d \leq 4 \text{ mm}$ | 1    | Fe/Zn 12c, Z275 | Fe/Zn 25c, Z350 |
| Screws with $d > 4 \text{ mm}$   | 2    | None | Fe/Zn 25c, Z350 |
| Steel plates up to 3 mm thickness | 3    | Fe/Zn 12c, Z275 | Stainless steel |
| Steel plates from 3 mm up to 5 mm in thickness | 2    | Fe/Zn 12c, Z275 | Fe/Zn 25c, Z350 |
| Steel plates over 5 mm thickness | None | None | Fe/Zn 25c, Z350 |

In this guide timber means solid timber, glued laminated timber, Kerto-S and Kerto-T. Due to its cross-veneers, Kerto-Q has better splitting resistance when compared to other timber when used in flatwise connections.

Wood-based panels should be CE-marked in accordance with EN 13986 (plywood, particleboard, OSB-board, medium fibreboard and hard fibreboard) or they should have a local type approval or statement/certificate from an institution approved by local building authorities that covers their use as load-bearing structures.
4. LOADING

Screws can be loaded laterally or axially. The loading can also be combined lateral and axial load.

Reductions in cross section should be taken into account when analysing the capacity of timber members. These reductions may be neglected if the screw diameter \(d_f\) is \(≤ 6\) mm or holes are position in the compressed side of the member and filled with a material of higher stiffness.

In compressed Kerto-to-Kerto joints, \(2/3\) of the perpendicular compression force can be transferred directly through contact from member to member. If the contact surfaces have been CNC-machined, \(3/4\) of the perpendicular compression force can be transferred directly through contact from member to member. Splitting of the compressed side in sloped connections, such as ridge connections, should be prevented by shaping the end of the member or installing a hard fibreboard or steel plate with a height of about \(3/4\) of the total height of the connection.

When a force in a connection acts at an angle to the grain, the screws of laterally suspended joints should ideally be positioned at the compressed side of the member. In these cases there is generally no need to check the tension capacity perpendicular to the grain. See Figure 5.

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### Table 2: Strength modification factors for service classes and load-duration classes \(k_{\text{mod}}\) and partial factors \(\gamma_M\) for material properties and resistances, 11

<table>
<thead>
<tr>
<th>MATERIAL</th>
<th>SERVICE CLASS</th>
<th>LOAD-DURATION CLASS</th>
<th>PERMANENT ACTION</th>
<th>LONG TERM ACTION</th>
<th>MEDIUM TERM ACTION</th>
<th>SHORT TERM ACTION</th>
<th>INSTANTANEOUS ACTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solid timber, round</td>
<td>1</td>
<td></td>
<td>0.60</td>
<td>0.70</td>
<td>0.80</td>
<td>0.90</td>
<td>1.10</td>
</tr>
<tr>
<td>timber, glued laminated</td>
<td>2</td>
<td></td>
<td>0.60</td>
<td>0.70</td>
<td>0.80</td>
<td>0.90</td>
<td>1.10</td>
</tr>
<tr>
<td>timber, Kerto LVL, plywood</td>
<td>3</td>
<td></td>
<td>0.50</td>
<td>0.55</td>
<td>0.65</td>
<td>0.70</td>
<td>0.90</td>
</tr>
<tr>
<td>Particleboard EN 312-4* and -5, OSB/2*, Hard fibreboard</td>
<td>1</td>
<td></td>
<td>0.30</td>
<td>0.45</td>
<td>0.65</td>
<td>0.85</td>
<td>1.10</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td></td>
<td>0.20</td>
<td>0.30</td>
<td>0.45</td>
<td>0.60</td>
<td>0.80</td>
</tr>
<tr>
<td>Particleboard EN 312-6* and -7, OSB/3, OSB/4</td>
<td>1</td>
<td></td>
<td>0.40</td>
<td>0.50</td>
<td>0.70</td>
<td>0.90</td>
<td>1.10</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td></td>
<td>0.30</td>
<td>0.40</td>
<td>0.70</td>
<td>0.70</td>
<td>0.90</td>
</tr>
<tr>
<td>Medium fibreboard: MBH, LA*, MBH.HLS, MDF.LA* and MDF.HLS</td>
<td>1</td>
<td></td>
<td>0.20</td>
<td>0.40</td>
<td>0.60</td>
<td>0.80</td>
<td>1.10</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td></td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>0.45</td>
<td>0.80</td>
</tr>
</tbody>
</table>

**Partial factors \(\gamma_M\) (EN 1995 recommended values and the Finnish NA values)**

| Fundamental combinations:            |                |                    |                  |                  |                    |                  |                    |
| Solid and Round timber in general   | 1.30           | 1.40               |                  |                  |                    |                  |                    |
| Softwood structural timber, strength class ≥ C35 | 1.30           | 1.25               |                  |                  |                    |                  |                    |
| Glued laminated timber               | 1.25           | 1.20               |                  |                  |                    |                  |                    |
| Plywood, OSB                         | 1.20           | 1.25               |                  |                  |                    |                  |                    |
| Particle- and fibreboards           | 1.30           | 1.25               |                  |                  |                    |                  |                    |
| Connections                         | 1.30           | according to timber material | | | | | |
| Accidental combination              | 1.00           | 1.00               |                  |                  |                    |                  |                    |

* Can only be used in service class 1

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![Figure 2: Forces for screw](image-url)
5. LATERALLY LOADED CONNECTIONS

The effect of screw threads is taken into account by using the effective diameter $d_{ef}$. For timber screws the equations for profiled nails are used, see 5.1. For screws the effective diameter $d_{ef}$ is calculated with equation (2) or (4). For lag screws with diameter $d \leq 6$ mm the equations for profiled nails are also used, see 5.1. For lag screws with $d \geq 6$ mm the equations for bolts are used, see 5.2. Depending on the penetration depth of the lag screw the effective diameter is equal to $d$ or calculated with equation (2).

For calculating the lateral load-capacity of the connection, the capacity of fasteners and the block shear in timber members should be checked. See Figure 3.

The design capacity of connection:

$$R_d = \frac{k_{mod} \cdot R_k}{\gamma_M}$$  \hspace{1cm} (7)

where:  
- $k_{mod}$ is the modification factor for duration of load and moisture content
- $\gamma_M$ is the partial factor for connection resistance

When connecting two different materials the smallest value of $k_{mod}/\gamma_M$ should be used.

5.1 LATERALLY LOADED SCREWS

The following guides may be used unless CE-mark or VTT statement given for design according to EN 1995 otherwise states, for example self-drilling screws with drill-bit.

If one of the following terms is fulfilled, and the penetration depth of the screw’s threaded part in the point side timber member is at least $8d_{ef}$, the characteristic lateral load-capacity, equation (8), may be multiplied by 1.15.

- The penetration depth of the threaded part in head side timber is at least $6d_{ef}$
- A steel plate on the head side
- A washer with a side length or a diameter of at least $3d$ and a thickness of at least $0.3d$ is used under the head. Washers should have a full bearing area.
- A wood-based panel (plywood, particleboard, OSB or hard fibreboard) with thickness of at least $2d_{ef}$ is under the head and the head diameter is at least $2d$.

5.1.1 TIMBER-TO-TIMBER CONNECTIONS

This method can be used with lag screws when the diameter is not more than $6$ mm and the method can be used with screws when, penetration depth $t_1$ is, with non-pre-drilled screws $\geq 7d_{ef}$ and with pre-drilled screws $\geq 4d_{ef}$ and penetration depth $t_2$ is with non-pre-drilled screws $\geq 8d_{ef}$ and with pre-drilled screws $\geq 4d_{ef}$. For Kerto-Q without pre-drilling the penetration depth $t_1$ may be $\geq 4d_{ef}$. See Figure 4.

![Figure 3: Laterally loaded connection](image)

![Figure 4: Definitions of $t_1$, $t_2$, and $t_3$](image)
The characteristic load-carrying capacity for a screw in single shear, when penetration depths \( t_1 \geq 8d_{ef} \) and \( t_2 \geq 12d_{ef} \)

\[
R_k = \begin{cases} 
120 \cdot d_{ef}^{1.7} & \text{non-pre-drilled} \\
130 \cdot d_{ef}^{1.8} & \text{pre-drilled}
\end{cases} \quad [N] \quad (8)
\]

where: \( d_{ef} \) is the effective diameter of the fastener, in mm

The penetration thicknesses \( t_1 \) and \( t_2 \) are defined in single and double shear connections as follows, see Figure 4:

- In a single shear connection \( t_1 \) is the thickness of the timber member at the head side and \( t_2 \) is the penetration depth of the point side.

- In a double shear connection \( t_1 \) is the minimum of the following: thickness of the timber member at the head side or the penetration depth of the point side and \( t_2 \) is the thickness of the central member.

- In a three-member connection, screws may overlap in the central member provided \((t - t_2)\) is greater than \(4d_{ef}\).

The design load-carrying capacity when \( t_1 \geq 8d_{ef} \) and \( t_2 \geq 12d_{ef} \)

\[
R_d = \frac{k_{mod} \cdot k_p \cdot k_t \cdot k_{h,k} \cdot R_k}{\gamma_M} \quad (9)
\]

where: \( k_{mod} \) is the modification factor for duration of load and moisture content

\( \gamma_M \) is the partial factor for connection resistance

When connecting two different materials the smallest value of \( k_{mod} / \gamma_M \) should be used.

\[
k_p = \left( \frac{\rho_c}{350} \right) \quad (10)
\]

If timber members do not have the same characteristic density \( \rho_c \) \((kg/m^3)\) the smallest value should be used. For Kerto-S and Kerto-Q the \( k_p = 1.171 \) and for Kerto-T the \( k_p = 1.082 \).

\[
k_t = \max \left\{ \frac{1 + 0.3 \cdot \frac{t_1 - 8d_{ef}}{8d_{ef}}}{1 + 0.3 \cdot \frac{t_2 - 12d_{ef}}{6d_{ef}}} \right\} \quad (11)
\]

with the following limits:

\[
k_t \leq \frac{M_y}{160d_{ef}^{2.6}} \quad (12)
\]
5.1.1.1 KERTO-TO-KERTO CONNECTIONS

Table 3: The lateral load-carrying capacity values of a single smooth wire nails without pre-drilling $R_k$ and $k_{mod} \cdot R_k$ [N] for a Kerto-to-Kerto flatwise connection (Kerto-S or Kerto-Q). Table values can be used when penetration lengths are $t_1 \geq 8d$ and $t_2 \geq 12d_{def}$ and head diameter $d_h \geq 1.8d$ and threaded part length $l_g \geq 12d_{def}$. The calculation has been done by using the Johansen yield theory according to Eurocode 5. Strength modification factors for service classes and load-duration classes are according to Table 2.

<table>
<thead>
<tr>
<th>Load-Duration Class and Service Class</th>
<th>Permanent Action</th>
<th>Medium Term Action</th>
<th>Short Term Action</th>
<th>Instantaneous Action</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$k_{mod} \cdot R_k$</td>
<td>$k_{mod} \cdot R_k$</td>
<td>$k_{mod} \cdot R_k$</td>
<td>$k_{mod} \cdot R_k$</td>
</tr>
<tr>
<td>$d$</td>
<td>1 and 2</td>
<td>1 and 2</td>
<td>1 and 2</td>
<td>1 and 2</td>
</tr>
<tr>
<td>3.8</td>
<td>755</td>
<td>453</td>
<td>378</td>
<td>604</td>
</tr>
<tr>
<td>4.2</td>
<td>898</td>
<td>539</td>
<td>449</td>
<td>718</td>
</tr>
<tr>
<td>4.6</td>
<td>1053</td>
<td>632</td>
<td>527</td>
<td>842</td>
</tr>
<tr>
<td>5.0</td>
<td>1217</td>
<td>730</td>
<td>609</td>
<td>974</td>
</tr>
<tr>
<td>6.0</td>
<td>1672</td>
<td>1003</td>
<td>836</td>
<td>1338</td>
</tr>
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</table>

5.1.1.2 KERTO-TO-TIMBER CONNECTIONS

Table 4: The lateral load-carrying capacity values of single smooth wire nails without pre-drilling $R_k$ and $k_{mod} \cdot R_k$ [N] for a Kerto-to-timber flatwise connection (Kerto-S or Kerto-Q and solid timber with strength class $\geq c24$). Table values can be used when penetration lengths are $t_1 \geq 8d$ and $t_2 \geq 12d_{def}$ and head diameter $d_h \geq 1.8d$ and threaded part length $l_g \geq 12d_{def}$. The calculation has been done by using the Johansen yield theory according to Eurocode 5. Strength modification factors for service classes and load-duration classes are according to Table 2.

<table>
<thead>
<tr>
<th>Load-Duration Class and Service Class</th>
<th>Permanent Action</th>
<th>Medium Term Action</th>
<th>Short Term Action</th>
<th>Instantaneous Action</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$k_{mod} \cdot R_k$</td>
<td>$k_{mod} \cdot R_k$</td>
<td>$k_{mod} \cdot R_k$</td>
<td>$k_{mod} \cdot R_k$</td>
</tr>
<tr>
<td>$d$</td>
<td>1 and 2</td>
<td>1 and 2</td>
<td>1 and 2</td>
<td>1 and 2</td>
</tr>
<tr>
<td>KERTO ON HEAD SIDE</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3.8</td>
<td>607</td>
<td>364</td>
<td>324</td>
<td>403</td>
</tr>
<tr>
<td>4.2</td>
<td>723</td>
<td>434</td>
<td>362</td>
<td>486</td>
</tr>
<tr>
<td>4.6</td>
<td>848</td>
<td>509</td>
<td>424</td>
<td>678</td>
</tr>
<tr>
<td>5.0</td>
<td>980</td>
<td>588</td>
<td>490</td>
<td>784</td>
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<tr>
<td>6.0</td>
<td>1349</td>
<td>809</td>
<td>675</td>
<td>1079</td>
</tr>
</tbody>
</table>

SOLID TIMBER ON HEAD SIDE

| $d$                                  | 3 and 2         | 3 and 2           | 3 and 2           | 3 and 2             |
| 3.8                                  | 504             | 302               | 252               | 403                 |
| 4.2                                  | 600             | 360               | 300               | 480                 |
| 4.6                                  | 703             | 422               | 352               | 562                 |
| 5.0                                  | 813             | 488               | 407               | 650                 |
| 6.0                                  | 1117            | 670               | 559               | 894                 |
5.1.2 PANEL-TO-TIMBER CONNECTIONS

The design capacity of single shear panel-to-timber connections, when the wood-based panel is through screwed on the head side of the screw and the point side penetration depth in timber is at least 8\(d_{ef}\), may be calculated according to expression (16). This method cannot be used for edgewise wood-based panel connections.

\[
R_d = \frac{k_{mod} \cdot k_f \cdot R_k}{\gamma_M} \min \left\{ \frac{t_2}{12d_{ef}} \right\} \tag{16} \]

where:

- \(k_{mod}\) is the modification factor for duration of load and moisture content
- \(\gamma_M\) is the partial factor for connection resistance
- \(R_k\) is calculated with (17) for screws with and without predrilling.
- \(d_{ef}\) is the effective diameter of the fastener, in mm

When \(t_2\) is at least 12\(d_{ef}\) the \(k_f\) can be calculated with (18), if \(t_2\) is less than 12\(d_{ef}\) \(k_f\) is 1.0.

\[
k_f = \begin{cases} 
0.5 + \frac{t}{12d_{ef}} & \text{for conifer plywood, particleboard, OSB} \\
0.6 + \frac{t}{9d_{ef}} & \text{for birch plywood} \\
0.7 + \frac{t}{8d_{ef}} & \text{for EN 622-1 hard fibreboard}
\end{cases} \tag{18} \]

with the following limits:

\[k_f \leq 1.2k_{\rho} \]

\(t\) is the thickness of the wood-based panel

\[
k_{\rho} = \sqrt[350]{\rho_k} \tag{19} \]

For the characteristic density \(\rho_k\) (kg/m\(^3\)) the value from the point side timber should be used. For Kerto-S and Kerto-Q the \(k_{\rho} = 1.171\) and for Kerto-T the \(k_{\rho} = 1.082\).

The effective diameter \(d_{ef}\) of the screw should not be more than 0.5\(t\) with plywood, particleboard and OSB and with hard fibreboard 0.67\(t\). In addition, with particleboard and OSB the maximum effective diameter of the screw should be no more than 5 mm.

Table 5: The lateral load-carrying capacity values of a single screw without pre-drilling \(R_k\) and \(k_{mod} \cdot R_k\) [N] for a panel-to-Kerto flatwise connection (Kerto-S or Kerto-Q and conifer plywood \(t = 18\) mm). If thicker conifer plywood or birch plywood is used, the calculated values are on the safe side. The calculation has been done by using the Johansen yield theory according to Eurocode 5. Strength modification factors for service classes and load-duration classes are according to Table 2.

<table>
<thead>
<tr>
<th>LOAD-DURATION CLASS AND SERVICE CLASS</th>
<th>PERMANENT ACTION</th>
<th>MEDIUM TERM ACTION</th>
<th>SHORT TERM ACTION</th>
<th>INSTANTANEOUS ACTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>(d)</td>
<td>(R_k)</td>
<td>k(_{mod}) \cdot R_k</td>
<td>k(_{mod}) \cdot R_k</td>
<td>k(_{mod}) \cdot R_k</td>
</tr>
<tr>
<td>3.8</td>
<td>688</td>
<td>1 and 2</td>
<td>3</td>
<td>1 and 2</td>
</tr>
<tr>
<td>4.2</td>
<td>796</td>
<td>413</td>
<td>344</td>
<td>550</td>
</tr>
<tr>
<td>4.6</td>
<td>890</td>
<td>478</td>
<td>398</td>
<td>637</td>
</tr>
<tr>
<td>5.0</td>
<td>990</td>
<td>534</td>
<td>445</td>
<td>712</td>
</tr>
<tr>
<td>6.0</td>
<td>1263</td>
<td>594</td>
<td>495</td>
<td>792</td>
</tr>
</tbody>
</table>
5.1.3 STEEL-TO-TIMBER CONNECTIONS
This method is for connections where the steel plate is on the head side. Screws are lag screws or anchor screws with a smooth shank thickness \(d_s\) the same as the screw nominal thickness \(d\) and the length of the smooth shank should be at least the same as the thickness of the steel plate \(t_s\). The penetration depth should be at least \(8d_{ef}\). The capacity of the steel plate should be checked according to EN 1993. This method cannot be used for edgewise Kerto connections. The edgewise Kerto steel-to-timber connections can be calculated according to EN 1995 and guidance provided in the Kerto product certificate.

The characteristic load-carrying capacity for a screw in single shear for steel-to-timber connection

\[
R_g = \frac{k_{mod} \cdot k_s \cdot R_k}{\gamma_M} \quad (20)
\]

where: 
- \(k_{mod}\) is the modification factor for duration of load and moisture content 
- \(\gamma_M\) is the partial factor for connection resistance 
- \(R_k\) is calculated with (21) for screws with and without predrilling.

\[
R_k = 120d_{ef}^{1.7} \quad [N] \quad (21)^{25}
\]

\(d_{ef}\) is the effective diameter of the fastener, in mm

The characteristic capacity can be increased by the following factor \(k_s\) if the point side penetration depth \(t_2 \geq 12d_{ef}\).

\[
k_s = \begin{cases} 
1.1 \cdot k_p & \text{for thin steel plate } t_s \leq 0.5d_{ef} \\
1.5 \cdot k_p & \text{for thick steel plate } t_s \geq d_{ef}
\end{cases} \quad (22)^{26}
\]

For screw with a penetration depth \(8d_{ef} \leq t_2 \leq 12d_{ef}\), the characteristic capacity can be increased by

\[
k_s = \begin{cases} 
0.2 + 0.9 \cdot \frac{t_2}{12d_{ef}} & \text{for thin steel plate } t_s \leq 0.5d_{ef} \\
0.6 + 0.9 \cdot \frac{t_2}{12d_{ef}} & \text{for thick steel plate } t_s \geq d_{ef}
\end{cases} \quad (23)^{27}
\]

The \(k_s\) factor with a steel plate thickness between a thin and thick plate, where \(0.5d_{ef} < t_s < d_{ef}\) should be calculated by linear interpolation.

The use of thick steel plate in equations (22) or (23) is allowed if the hole diameter \(D\) in the steel plate is not more than \(1.1d\).

\[
k_p = \sqrt[3]{\frac{\rho_k}{350}} \quad (24)^{28}
\]

For the characteristic density \(\rho_k\) (kg/m³) the value from the point side timber should be used. For Kerto-S and Kerto-Q, the \(k_p = 1.171\) and for Kerto-T the \(k_p = 1.082\).

5.2 LATERALLY LOADED LAG SCREWS
For calculating the shear capacity of the connection, the capacity of fasteners and block shear in timber members should be checked. The following rules are valid for predrilled lag screws with \(d \geq 6\ mm\).

5.2.1 TIMBER-TO-TIMBER CONNECTIONS
The characteristic load-carrying capacity for a fastener per shear plane:

\[
R_k = \min \left(0.4 \cdot f_{h,k} \cdot t_u \cdot d_{ef} \cdot \sqrt{1 + \frac{3 \cdot M_y}{f_{h,k} \cdot d_{ef} \cdot t_u^2}} \right) \quad (25)^{29}
\]

where:

\[
f_{h,k} = \min(f_{h,1,k}; f_{h,2,k}; f_{h,s,k}) \quad (27)^{31}
\]

\(t_1\) and \(t_2\) are the timber or board thicknesses or penetration depths of outer members

\(f_{h,1,k}\) and \(f_{h,2,k}\) are the characteristic embedment strengths of outer timber members

\(f_{h,s,k}\) is the characteristic embedment strength of inner timber member in two shear plane connection

\(d_{ef}\) is the effective diameter of the fastener

The characteristic value for the yield moment:

\[
M_y = 0.3 \cdot f_{u,k} \cdot d^2 \quad [Nmm] \quad (28)^{32}
\]

where: \(f_{u,k}\) is the characteristic tensile strength, in N/mm²

\(d\) is the effective diameter of the fastener, in mm
The characteristic embedment strength, at an angle \( \alpha \) to the grain:

\[
f_{h,\alpha,k} = \frac{f_{h,0,k}}{k_{90} \cdot \sin^2 \alpha + \cos^2 \alpha} \quad \text{[N/mm}^2] \quad (29)_{33}
\]

where:

\[
f_{h,0,k} = \begin{cases} 
0.082 \cdot (1 - 0.01d_{ef}) \cdot \rho_k & \text{for flatwise connections} \\
37 \cdot k_Q \cdot (1 - 0.01d_{ef}) & \text{for edgewise connections} 
\end{cases} \quad \text{[N/mm}^2] \quad (30)_{34}
\]

\[
k_Q = \begin{cases} 
1 & \text{for Kerto-Q} \\
1.30 + 0.015d_{ef} & \text{for Kerto-S and Kerto-T} \\
1.15 + 0.015d_{ef} & \text{for Kerto-Q} \\
1.35 + 0.015d_{ef} & \text{for softwood} \\
0.90 + 0.015d_{ef} & \text{for hardwoods}
\end{cases} \quad (32)_{36}
\]

for Kerto-Q \( f_{h,\alpha,k} = f_{h,45,k} \) when \( 45^\circ \leq \alpha \leq 90^\circ \) \( 37 \)

\( \rho_k \) is the characteristic timber density, in kg/m\(^3\)

\( d_{ef} \) is the effective diameter of the fastener, in mm

\( \alpha \) is the angle between the load and the grain direction

### 5.2.2 PANEL-TO-TIMBER CONNECTIONS

The characteristic load-carrying capacity of a panel-to-timber connection shall be calculated with the equations presented in timber-to-timber connections, 5.2.1, where the thickness of the wood-based panel is at least according equation (33).

\[
t_{panel} \geq \frac{80 \cdot t}{f_{h,panel,k}} \quad \text{[mm]} \quad (33)_{38}
\]

where:

\( f_{h,panel,k} \) is the characteristic embedment strength of the panel, in N/mm\(^2\)

\( d_{ef} \) is the effective diameter of the fastener, in mm

For plywood the following embedment strength, should be used at all angles to face grain:

\[
f_{h,panel,k} = 0.11 \cdot (1-0.01d_{ef}) \cdot \rho_k \quad \text{[N/mm}^2] \quad (34)_{39}
\]

where:

\( \rho_k \) is the characteristic density of the plywood, in kg/m\(^3\)

\( d_{ef} \) is the effective diameter of the fastener, in mm

For particleboard and OSB the following embedment strength should be used for all loading directions:

\[
f_{h,k} = 50 \cdot d_{ef}^{-0.6} \cdot t^{-0.2} \quad \text{[N/mm}^2] \quad (35)_{40}
\]

where:

\( d_{ef} \) is the effective diameter of the fastener, in mm

\( t \) is the panel thickness, in mm

### 5.2.3 STEEL-TO-TIMBER CONNECTIONS

The capacity of steel plate should be checked according to EN 1993.

In compressed steel plate connections the buckling length of 0.8 \( L_e \) can be generally used for outside plates, where \( L_e \) is the distance between the first fasteners at opposite sides of the connection. The buckling does not need to be taken into account for steel plates installed inside a timber member if the expansion of timber members is prevented, for example, by using tie bolts and limiting the size of the slot for the steel plate to maximum of 1.25 \( t_t \).

The drying shrinkage perpendicular to the grain direction should be taken into account with steel-to-timber connections.

It should be taken into account that the load-carrying capacity of steel-to-timber connections with a loaded end may be reduced by failure along the perimeter of the fastener group. There are two types of loaded end failures: block shear and plug shear failure.

The characteristic load-carrying capacity per screw for a thin steel plate, with \( t_t \leq 0.5d_{ef} \) in single shear:

\[
R_k = \min \left\{ \frac{0.4 \cdot f_{h,k} \cdot t \cdot d_{ef}}{2 \cdot \sqrt{M_y \cdot f_{h,k} \cdot d_{ef}}} \right\} \quad (36)_{41}
\]

The characteristic load-carrying capacity per screw for a thick steel plate, with \( t_t \geq d_{ef} \) in single shear:

\[
R_k = \min \left\{ \frac{f_{h,k} \cdot t \cdot d_{ef}}{3 \cdot \sqrt{M_y \cdot f_{h,k} \cdot d_{ef}}} \right\} \quad (37)_{42}
\]

where:

\( f_{h,k} \) is the characteristic embedment strength of the timber member, equation (27)

\( t \) is the thickness of the timber member

\( d_{ef} \) is the effective diameter of the fastener

\( M_y \) is the characteristic fastener yield moment, equation (28)

The characteristic load-carrying capacity of connections with a steel plate thickness between a thin and thick plate, where \( 0.5d_{ef} < t_t < d_{ef} \), should be calculated by linear interpolation between equations (36) and (37).
5.2.4 EFFECTIVE NUMBER OF FASTENERS

For one row of \( n \) fasteners parallel to the grain direction, the load-carrying capacity parallel to grain should be calculated using the effective number of fasteners \( n_{ef} \):

\[
n_{ef} = \min\left\{ \frac{n_i}{0.9}, \frac{a \cdot t}{50 \cdot d_{ef}^2} \right\}
\]

where: \( n_i \) is the number of fasteners in a row \( i \)

\( d_{ef} \) is the effective diameter of the fastener

\[
da = \begin{cases} \min(a_1; a_3), & \text{when } n_i \geq 2 \\ a_3, & \text{when } n_i = 1 \end{cases}
\]

\( a_1 \) is the spacing of fasteners in the grain direction

\( a_3 \) is the end distance of fasteners

\[
t = \begin{cases} \min(t_1; t_2), & \text{connection with timber only in outer members} \\ \min(2t_1; 2t_2; t_3), & \text{other two and multiple shear connection} \end{cases}
\]

\( t_1 \) and \( t_2 \) are the thicknesses of outer timber members, should be discarded if the outer member is not timber

\( t_3 \) is the thickness of the inner member of double shear connections or the smallest thickness of inner member of a multiple shear connection

6. BLOCK SHEAR FAILURE

6.1 CONNECTION FORCES AT THE ANGLE OF GRAIN

When a force in a connection acts at an angle to the grain, see Figure 5, the possibility of splitting caused by the tension force component, \((F_{Ed} \cdot \sin \alpha)\), perpendicular to grain, should be taken into account.

For solid timber, glued laminated timber, Kerto-S, Kerto-T and Kerto-Q edgewise, the following should be satisfied:

\[
F_{v,Ed} \leq F_{90,d}
\]

where: \( F_{90,d} \) is the design splitting capacity

\[
F_{v,Ed} = \max\{F_{v,Ed1}; F_{v,Ed2}\}
\]

\( F_{v,Ed} \) and \( F_{v,Ed2} \) are the design shear forces on either side of the connection caused by the connection force component \((F_{Ed} \cdot \sin \alpha)\) perpendicular to the grain

For softwood, the characteristic splitting capacity:

\[
F_{90,k} = 14 \cdot b \cdot \frac{h_v}{\sqrt{1 - \frac{h_v}{h}}}
\]

where: \( h_v \) is the loaded edge distance to the centre of the most distant fastener, in mm, see Figure 5

\( b \) is the timber member height, in mm

\( b \) is the member thickness, yet not more than the penetration depth, in mm

The equation (43) does not need to be checked for flatwise Kerto-Q connections since flatwise Kerto-Q is not sensitive to splitting caused by connection forces at an angle to the grain due to its cross-veneers.

6.2 BLOCK SHEAR FAILURE

Timber failure capacity of the joint area can be calculated using the method presented in RIL 205-1-2009 in section 8.2.4S Lohkamis-murto. When using this method, the connection area for splitting and row shear is taken into account by using the effective number of fastener \( n_{ef} \), see equation (38). This method cannot be used for edgewise Kerto connections.

When connection force components are parallel to the grain, the timber failure should be checked at tension loaded member ends. There are two types of timber failure modes: block shear and plug shear.

The block and plug shear capacities are not checked for connections where all the fasteners are in a single row parallel to the grain \((n_2 = 1)\).

Block shear may need to be checked if the centre member is screwed from both sides and the screws are overlapping.

If timber member \( t_1 \) has fasteners from opposite sides and the effective thickness \( t_{ef} \) is \( 0.5t_1 \); for steel-to-timber connections the block shear capacity should also be checked.
The characteristic plug shear capacity:

\[ F_{ps,k} = L_{net,d} \cdot t_{ef} \cdot f_{t,0,k} + (a_1 \cdot n_1 - 1) \cdot f_{t,0,k} \]

where:

\[ L_{net,d} = (n_2 - 1) \cdot (a_2 - D) \]

\[ t_{ef} = \frac{R_k}{d_{ef} \cdot f_{h,0,k}} \]

\[ f_{h,0,k} = \begin{cases} 0.082 \cdot (1 - 0.01d_{ef}) \cdot \rho_k & \text{In general} \\ 37 \cdot (1 - 0.01d_{ef}) & \text{for Kerto-Q} \end{cases} \]

\[ \rho_k \text{ is the characteristic timber density, in kg/m}^3 \]

\[ R_k \text{ is the characteristic load-carrying capacity per shear plane per fastener} \]

\[ f_{h,0,k} \text{ is the characteristic embedment strength} \]

\[ d_{ef} \text{ is the effective diameter of the fastener} \]

The characteristic block shear capacity of a timber member:

\[ F_{bt,k} = L_{net,d} \cdot t_1 \cdot k_{bt} \cdot f_{t,0,k} \]

where:

\[ k_{bt} = \begin{cases} 1.50, & \text{for solid wood and glued laminated timber} \\ 1.25, & \text{for Kerto-LVL} \end{cases} \]

The characteristic block shear capacity of a Kerto-Q member:

\[ F_{bt,k} = \max \left\{ \begin{array}{l} \frac{L_{net,d} \cdot t_1 \cdot f_{t,0,k} + 0.7 \cdot L_{net,v} \cdot t_1 \cdot f_{v,k}}{L_{net,v}} \\ \frac{L_{net,d} \cdot t_1 \cdot k_{bt} \cdot f_{t,0,k}}{L_{net,v}} \end{array} \right\} \]

\[ f_{v,k} \text{ is the edgewise shear strength} (f_{v,0,edge,k} = 4.5 \text{ N/mm}^2) \]

\[ L_{net,v} = 2 \cdot (a_3 + (n_1 - 1) \cdot (a_1 - D)) \]

\[ 7. \text{ AXIALLY LOADED SCREWS} \]

For the verification of resistance of axially loaded screws, the following failure modes should be taken into account:

- The withdrawal failure of the threaded part of the screw \( f_{wd} \)
- The tear-off failure of the screw head in screws used in combination with steel plates, the tear-off resistance of the screw head should be greater than the tensile strength of the screw \( f_{wd} \)
- The pull-through failure of the screw head \( f_{head} \)
- The tensile failure of a screw \( f_{td} \)
- The buckling failure of the screw when loaded in compression
- Failure along the circumference of a group of screws used in conjunction with steel plates (block shear or plug shear)

The characteristic withdrawal capacity, for screws with \( 6 \text{ mm} \leq d \leq 12 \text{ mm} \) and inner threaded diameter \( 0.6d \leq d_i \leq 0.75d \):

\[ F_{ax,a,Rk} = \frac{n_{ef} \cdot f_{ax,k} \cdot d \cdot t_{ef} \cdot k_d}{1.2 \cos^2 \alpha + \sin^2 \alpha} \]
where: \(d\) is the outer threaded diameter, in mm

\[d_i\] is the inner threaded diameter (root diameter), in mm

\[f_{ax,k} = \frac{0.52 \cdot \rho_k^{0.8}}{d^{0.5} \cdot l_{ef}^{0.1}} \quad [N/mm^2] \quad (54)\]

\[k_d = \min \left[ \frac{d}{8} \right] \quad [\] \quad (55)\]

\(n_{ef}\) is the effective number of screws, see (62)

\(l_{ef}\) is the penetration length of the threaded part, in mm

\(\rho_k\) is the characteristic density, in kg/m³

\(\alpha\) is the angle between the screw axis and the grain direction, with \(30 \leq \alpha \leq 90\degree\), see Figure 16

For screws with \(d < 6\) mm, \(d > 12\) mm or \(d > 0.75d\), the characteristic withdrawal capacity should be taken as:

\[F_{ax,\alpha,Rk} = \frac{n_{ef} \cdot f_{ax,k} \cdot d \cdot l_{ef}}{1.2 \cos^2 \alpha + \sin^2 \alpha \left( \frac{\rho_k}{\rho_a} \right)^{0.8}} \quad [N] \quad (56)\]

where: \(f_{ax,k}\) is the characteristic withdrawal parameter perpendicular to the grain determined in accordance with EN 14592 for the associated density \(\rho_d\)

\(\rho_a\) is the associated density for \(f_{ax,k}\) in kg/m³

\(d\) is the outer threaded diameter, in mm

\(n_{ef}\) is the effective number of screws, see (62)

\(l_{ef}\) is the penetration length of the threaded part, in mm

\(\rho_k\) is the characteristic density, in kg/m³

\(\alpha\) is the angle between the screw axis and the grain direction, with \(30 \leq \alpha \leq 90\degree\), see Figure 16

For screws according to (1) with \(4 \leq d \leq 6\) mm, the characteristic withdrawal parameter may be calculated accordingly; applies for solid wood, glued laminated timber and flatwise connections of Kerto-S, Kerto-Q, Kerto-T, Kerto-Kate and Metsä Wood Spruce:

\[f_{ax,k} = \left( \frac{8d}{l_{ef}} \right)^{0.2} \frac{\rho_k^{0.8}}{30} \quad [N/mm^2] \quad (57)\]

where: \(d\) is the outer threaded diameter, in mm

\(l_{ef}\) is the penetration length of the threaded part, in mm

\(\rho_k\) is the characteristic density, in kg/m³; then \(\rho_d = \rho_k\) in equation (56)

For connections to edgewise Kerto-S or Kerto-Q with screws in accordance with EN 14592 with a nominal diameter \(4.5 \leq d \leq 8\) mm, the characteristic withdrawal capacity may be calculated according to equation (58) provided that the inner threaded diameter \(d_i\) was 0.7d and smooth shank diameter \(d_s\) was 0.8d if smooth shank penetrates to the edge of the Kerto-S or Kerto-Q.

\[F_{ax,Rk} = n_{ef} \cdot f_{ax,k} \cdot d \cdot l_{ef} \quad (58)\]

where: \(d\) is the outer threaded diameter, in mm

\(d_i\) is the inner threaded diameter (root diameter)

\(d_s\) is the smooth shank diameter

\(f_{ax,k} = 10 \quad N/mm^2\), for edgewise Kerto-S and edgewise Kerto-Q

\(n\) is the number of screws acting together in a connection

\(l_{ef}\) is the penetration length of the threaded part

### Table 6: The characteristic withdrawal strength parameter values \(f_{ax,k}\) [N/mm²] for some screws in edgewise Kerto-S and Kerto-Q

<table>
<thead>
<tr>
<th>Screw</th>
<th>KERTO-S</th>
<th>KERTO-Q</th>
</tr>
</thead>
<tbody>
<tr>
<td>SFS Intec WT-T (d = 6.5) mm</td>
<td>11.2</td>
<td>-</td>
</tr>
<tr>
<td>SFS Intec WT-T (d = 8.2) mm</td>
<td>14.6</td>
<td>-</td>
</tr>
<tr>
<td>Würth Assy Plus (d = 6) mm</td>
<td>13.0</td>
<td>-</td>
</tr>
<tr>
<td>Würth Assy Plus (d = 8) mm</td>
<td>10.4</td>
<td>-</td>
</tr>
<tr>
<td>Würth Assy VG Plus (d = 6) mm</td>
<td>11.8</td>
<td>-</td>
</tr>
<tr>
<td>Würth Assy VG Plus (d = 8) mm</td>
<td>14.5</td>
<td>13.4</td>
</tr>
</tbody>
</table>

In Table 6, characteristic withdrawal strength parameters are presented for self-drilling SFS Intec WT-T, Würth Assy Plus and Würth Assy VG Plus screws. General value may also be used.

The characteristic pull-through resistance of connections with axially loaded screws should be taken as:

\[F_{ax,\alpha,Rk} = \frac{n_{ef} \cdot f_{head,k} \cdot d^2_h \cdot \rho_k^{0.8}}{(\rho_a)\left(\frac{\rho_k}{\rho_a}\right)^{0.8}} \quad [N] \quad (59)\]

where: \(f_{ax,\alpha,Rk}\) is the characteristic pull-through capacity of the connection at an angle \(\alpha\) to the grain, with \(30 \leq \alpha \leq 90\degree\), see Figure 16

\(f_{head,k}\) is the characteristic pull-through parameter of the screw determined in accordance with EN 14592 for the associated density \(\rho_a\)

\(d_h\) is the head diameter, in mm

\(n_{ef}\) is the effective number of screws, see (62)

\(\rho_k\) is the characteristic density, in kg/m³

\(\rho_a\) is the associated density for \(f_{head,k}\) in kg/m³

The characteristic tensile resistance of the connection (head tear-off or tensile capacity of shank), should be taken as:

\[F_{t,\alpha,Rk} = n_{eff} \cdot f_{tens,k} \quad (60)\]

where: \(f_{tens,k}\) is the characteristic tensile capacity of the screw determined in accordance with EN 14592

\(n_{ef}\) is the effective number of screws, see (62)
If the characteristic tensile capacity is not given, the design value can be calculated for timber-to-timber connections using the minimum tensile strength $f_{u,k} = 500 \text{ N/mm}^2$ and the minimum inner threaded diameter $0.6d$:

$$ F_{t,Rd} = n_{ef} \cdot \frac{n_{ef} \cdot \pi \cdot \left(\frac{1.1 \cdot 0.6d}{2}\right)^2}{\gamma_{M2}} \quad (61) $$

where: $\gamma_{M2}$ is the partial factor for the tension failure of steel fasteners according to the actual NA of EN 1993.

For a connection with a group of screws loaded by a force component parallel to the shank, the effective number of screws is given by:

$$ n_{ef} = n \cdot 0.9 \quad (62) $$

where: $n$ is the number of screws acting together in a connection.

Table 7: The characteristic axial capacity values of a single screw without pre-drilling $R_k$ and $\gamma_{mod} \cdot R_g$ [N] for an edgewise Kerto connection (Kerto-S or Kerto-Q) in service class 1 and 2 where screws are at right angles to the edge. The calculation is done by using equation (58). For connections with more than one screw the capacity is calculated by taking the effective number of screws into account with (62).

<table>
<thead>
<tr>
<th>$d$ (mm)</th>
<th>$l_{ef}$ (mm)</th>
<th>Permanent Action $R_k$</th>
<th>Medium Term Action $R_k$</th>
<th>Short Term Action $R_k$</th>
<th>Instantaneous Action $R_k$</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.5</td>
<td>30</td>
<td>1350</td>
<td>810</td>
<td>1080</td>
<td>1215</td>
</tr>
<tr>
<td>5.0</td>
<td>35</td>
<td>1750</td>
<td>1050</td>
<td>1400</td>
<td>1575</td>
</tr>
<tr>
<td>5.5</td>
<td>40</td>
<td>2200</td>
<td>1320</td>
<td>1760</td>
<td>1980</td>
</tr>
<tr>
<td>6.0</td>
<td>45</td>
<td>2700</td>
<td>1620</td>
<td>2160</td>
<td>2430</td>
</tr>
<tr>
<td>6.5</td>
<td>50</td>
<td>3250</td>
<td>1950</td>
<td>2600</td>
<td>2925</td>
</tr>
<tr>
<td>7.0</td>
<td>55</td>
<td>3850</td>
<td>2310</td>
<td>3080</td>
<td>3465</td>
</tr>
</tbody>
</table>

8. INCLINED SCREWED CONNECTIONS

8.1 CROSS SCREW CONNECTION

The cross screw connection is built up from symmetrical screw pairs, Figure 7 (a), in which one screw is under compression and the other under tension. The characteristic load-carrying capacity of the cross screw connection

$$ R_{2D,Rk} = n_p \cdot 0.9 \cdot \left( R_{C,Rk} + R_{T,Rk} \right) \cdot \cos \alpha \quad (63) $$

where: $n_p$ is the number of screw pairs in the joint, $\alpha$ is the screw angle ($30^\circ \leq \alpha \leq 60^\circ$), see Figure 7 (a).

The characteristic compression capacity of the screw for solid timber and glued laminated timber

$$ R_{C,Rk} = \min \left\{ \frac{f_{ax,\alpha,1,k} \cdot d \cdot l_{g,1}}{0.8 f_{lens,k}}, \frac{f_{ax,\alpha,2,k} \cdot d \cdot l_{g,2}}{0.8 f_{lens,k}} \right\} \quad (64) $$

The characteristic compression capacity of the screw for Kerto-S and Kerto-Q

$$ R_{C,Rk} = \min \left\{ \frac{f_{ax,\alpha,1,k} \cdot d \cdot l_{g,1}}{0.8 f_{lens,k}}, \frac{f_{ax,\alpha,2,k} \cdot d \cdot l_{g,2}}{0.8 f_{lens,k}} \right\} \quad (65) $$

The characteristic withdrawal capacity of the screw for solid timber and glued laminated timber

$$ R_{T,Rk} = \min \left\{ \frac{f_{ax,\alpha,1,k} \cdot d \cdot l_{g,1}}{0.8 f_{lens,k}}, \frac{f_{ax,\alpha,2,k} \cdot d \cdot l_{g,2}}{0.8 f_{lens,k}} \right\} \quad (66) $$

These rules concern the design of single shear connections according to Figure 7, where the screw inclination angle $\alpha$ should be $30^\circ \leq \alpha \leq 60^\circ$, both in regard to the connection force and screwing surface. In two dimensionally inclined connections the screw axis is parallel to the plane defined by the connection force direction and the normal of the joint surface. The head side timber member ($t_1$) may be replaced with a steel plate if the screw head has full bearing area onto the steel plate for Figure 7 (b) tension screw connection. The screws should be self-drilling and fully threaded or partly threaded, where the smooth part diameter $d_s \leq 0.8d$, where $d$ is the outer thread diameter.

Different or supplementary connection types and screw specifications differing from EN 1995 may be used according to European Technical Approval (ETA) or VTT statement.

Figure 7: Two dimensionally inclined screwed connections (a) cross screw connection (b) tension screw connection
The characteristic withdrawal capacity of the screw for Kerto-S and Kerto-Q

\[ R_{f, R_k} = \min \left( \frac{f_{ax,1,k} \cdot d \cdot l_{g,1} + f_{head,k} \cdot d^2}{f_{tens,k}} \right) \]  

where:

\[ f_{ax,1,k} = \frac{f_{ax,k} \cdot k_d}{1.2 \cos^2 \alpha + \sin^2 \alpha} \]  

when \( 6 \text{ mm} \leq d \leq 12 \text{ mm} \) and \( d \leq 0.75d \)

\[ f_{ax,1,k} = \frac{f_{ax,k} \cdot \left( \frac{\rho_A}{\rho_K} \right)^{0.8}}{1.2 \cos^2 \alpha + \sin^2 \alpha} \]  

when \( d > 6 \text{ mm} \), \( d > 12 \text{ mm} \) or \( d > 0.75d \)

for \( f_{ax,1,k} \), see section 7, equations (53) and (56)

\( d \) is the outer threaded diameter

\( l_{g,1} \) is the penetration length of the threaded part in the head side member

\( l_{g,2} \) is the penetration length of the threaded part in the point side member

\( f_{tens,k} \) is the characteristic tensile capacity of the screw determined in accordance with EN 14592. Some values are given in Table 9.

\[ f_{ax,45,k} = \frac{f_{ax,45,k} \cdot \left( \frac{\alpha}{150} + 0.7 \right) \cdot \left( \frac{8d}{l_{g,1}} \right)^{0.2}}{} \]  

\( f_{ax,45,k} \) is the characteristic withdrawal strength parameter for a screw, which is determined at an angle of 45º and penetration length \( l_{g,2} \geq 8d \) separately for flatwise and edgewise joints of Kerto-S and Kerto-Q according to EN 14592. Some values are given in Table 8.

\( \alpha \) is the screw angle (30º ≤ \( \alpha \) ≤ 60º), see Figure 7 (a)

\( f_{head} \) is the characteristic pull-through parameter of the screw for the associated density \( \rho_d \)

\( d_h \) is the head diameter

\( \rho_k \) is the characteristic density, in kg/m³

\( \rho_A \) is the associated density for \( f_{head,k} \), in kg/m³

The pull through strength of screw head is determined for Kerto-S and Kerto-Q in accordance with EN 14592 or when the angle between the screw axis and the grain is 45º, it may be calculated by equation (71), when \( d_h \leq 2d \).

\[ f_{head,45,k} = 57 \left( \frac{d_h}{d} - 1 \right) \]  

Table 8: Characteristic withdrawal strength parameters \( f_{ax,45,k} \) [N/mm²] for threaded part of general, ABC Spax-S, Würth AMO III, SFS Intec WT-T and Würth Assy VG Plus screws

<table>
<thead>
<tr>
<th>Material and screwing surface</th>
<th>direction (^a)</th>
<th>Screw diameter ( d ) [mm]</th>
<th>General / Spax-S</th>
<th>AMO III</th>
<th>SFS WT-T</th>
<th>VG Plus</th>
</tr>
</thead>
<tbody>
<tr>
<td>flatwise Kerto-S and Kerto-Q</td>
<td>0°</td>
<td>5.0–7.0</td>
<td>14.0</td>
<td>11.0</td>
<td>12.0</td>
<td>15.5</td>
</tr>
<tr>
<td>flatwise Kerto-S (^b)</td>
<td>45° – 90°</td>
<td>14.0</td>
<td>11.5</td>
<td>12.0</td>
<td>15.5</td>
<td>15.5</td>
</tr>
<tr>
<td>flatwise Kerto-Q (^b)</td>
<td>45° – 90°</td>
<td>14.0</td>
<td>11.0</td>
<td>12.0</td>
<td>15.5</td>
<td>17.0</td>
</tr>
<tr>
<td>Kerto-S, edge or end (^c)</td>
<td>0° / 90°</td>
<td>12.0</td>
<td>9.5</td>
<td>10.5</td>
<td>13.5</td>
<td>12.5</td>
</tr>
<tr>
<td>Kerto-Q, edge or end (^c)</td>
<td>0° / 90°</td>
<td>13.5</td>
<td>10.5</td>
<td>10.5</td>
<td>13.5</td>
<td>13.0</td>
</tr>
</tbody>
</table>

\(^a\) Direction between connection force and the grain direction of the outer veneers

\(^b\) These values may also be used for three dimensionally inclined screwed connections when \( \beta = 45° \)

\(^c\) Screws are parallel to the veneers

Table 9: Characteristic tensile capacity \( f_{head,k} \) [kN] for general, ABC Spax-S carbon steel, Würth AMO III, SFS Intec WT-T and Würth Assy VG Plus screws

<table>
<thead>
<tr>
<th>Screw diameter ( d ) [mm]</th>
<th>General</th>
<th>Spax-S</th>
<th>AMO III</th>
<th>SFS WT-T</th>
<th>VG Plus</th>
</tr>
</thead>
<tbody>
<tr>
<td>5.0</td>
<td>3.5</td>
<td>7.9</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>6.0</td>
<td>5.1</td>
<td>11.3</td>
<td>-</td>
<td>-</td>
<td>11.3</td>
</tr>
<tr>
<td>6.5</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>10.0</td>
<td>-</td>
</tr>
<tr>
<td>7.0</td>
<td>6.9</td>
<td>15.4</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>7.5</td>
<td>-</td>
<td>9.0</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>8.0</td>
<td>9.0</td>
<td>17.0</td>
<td>-</td>
<td>-</td>
<td>18.9</td>
</tr>
<tr>
<td>8.2</td>
<td>-</td>
<td>-</td>
<td>19.0</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>10.0</td>
<td>14.1</td>
<td>28.0</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>
8.2 TENSION SCREWED CONNECTION

In a joint consisting of only screws in tension, a contact between the wood members is required. Tension screws connection should not be used in conditions where wood drying could cause a gap over 0.2d.

The gap is determined from the wood shrinkage at a distance of the screw length \((L \cdot \sin \alpha)\).

The characteristic load-carrying capacity of the tension screw connection, see Figure 7 (b)

\[
R_k = n^{0.9} R_{T,Rk}(\cos \alpha + \mu \sin \alpha)
\]  

where: 
- \(n\) is the number of screws in the connection
- \(R_{T,Rk}\) is the characteristic withdrawal capacity, for solid wood and glued laminated timber (66) and for Kerto-S and Kerto-Q (67)
- \(\alpha\) is the screw angle \((30^\circ \leq \alpha \leq 60^\circ)\), see Figure 7 (b)
- \(\mu\) is the kinetic friction coefficient between the members, the following values may be used:
  - 0.26 for untreated edgewise Kerto-to-Kerto or timber (66)
  - 0.30 for steel-to-timber connections
  - 0.40 for untreated flatwise Kerto-to-Kerto connections

8.3 THREE DIMENSIONALLY INCLINED SCREWED CONNECTION

The following rules may be used for single shear Kerto-to-Kerto (Kerto-S or Kerto-Q) connections built up from three dimensionally inclined screw pairs according to Figure 8. The loading should be in the longitudinal direction of Kerto, parallel to the grain direction of face veneers. In three dimensionally inclined screwed connections, the screwing angle \(\alpha\) should be \(30^\circ \leq \alpha \leq 60^\circ\) in regards to the thickness direction of Kerto and the screwing angle \(\beta\) should be \(\beta \leq 45^\circ\) in regards to the screw axis and the longitudinal direction. Separate rules are given for three dimensionally inclined screwed connections, depending on whether there is a gap between Kerto members.

Connections without joint gap

When the connection members are compressed together, the characteristic load-carrying capacity of the three dimensional screw connection

\[
R_{3D,Rk} = R_{2D,Rk} \cos \beta
\]  

where: 
- \(R_{2D,Rk}\) is the load-carrying capacity of two dimensional cross screwed connections calculated with equation (63) with screwing angle \(\alpha\)
- \(\beta\) is the screw angle between axis and longitudinal direction

Connections with joint gap

When a gap at maximum of 2.5d wide is left between connection members, the characteristic load-carrying capacity of the three dimensional screw connection

\[
R_{3D,g,Rk} = \sqrt{n R_{v,Rk} \sin \alpha \cdot R_{2D,g,Rk} \cos \beta} \leq R_{3D,Rk}
\]  

where: 
- \(n\) is the number of screws in the connection
- \(R_{v,Rk}\) is the lateral load-carrying capacity per screw, see 5.1.1
- \(\alpha\) is the screw angle \((30^\circ \leq \alpha \leq 60^\circ)\), see Figure 8

8.4 CONNECTION DETAILING

Timber should be pre-drilled when the diameter \(d\) of the screw exceeds 8 mm or the diameter of the smooth shank \(d_s\) exceeds 6 mm. The diameter of pre-drilled holes for non-self-drilling screw should be \(D = 0.5d - 0.7d\) but not more than the inner threaded diameter \(d_i\).

The thickness of the member should be at least:

\[
t = \max \left\{ \frac{5d}{(10d - 30) \cdot \frac{\rho_k}{400}} \right\} \text{ [mm]}
\]  

where: 
- \(\rho_k\) is the characteristic density, in kg/m³
- \(d\) is the screw diameter, in mm

The minimum thickness of a Kerto-Q member is 3d at the head side of the screw and at the point side member it is determined by the required penetration length of the screw.
General spacings and end and edge distances are presented in Table 12 and Table 13. These values are valid for cross screw connections, when the compressed and tensioned fasteners of the screw pairs are placed to separate longitudinal rows parallel to the grain so that spacing between the rows $a_2$ is $4d$ and the staggered distance between the screw heads of a screw pair is not more than $3t_1$ parallel to the grain.

In the same connection, different types or sizes of screws may not be combined. All the screws are placed with the same inclination angles $\alpha$ and $\beta$. The screws are positioned centrally to the connection force. The screws are screwed deep enough so that the screw head is in full contact with the member surface. The minimum point side penetration depth of the threaded part should be $6d$. The members should be compressed together so that no gaps are present, except for the three dimensionally inclined screwed connection designed for a specific gap size ($\leq 2.5d$).

In three-member flatwise connection screws may overlap in the central member provided that $(t_2 - h)$ is greater than $3d$, see Figure 10. For edgewise screws overlap is not allowed.
9. COMBINED LATERALLY AND AXIALLY LOADED SCREWS

For connections subjected to a combination of axial load $F_{ax}$ and lateral load $F_{v}$, the following expression should be satisfied:

$$\left( \frac{F_{ax,d}}{R_{ax,d}} \right)^2 + \left( \frac{F_{v,d}}{R_{v,d}} \right)^2 \leq 1$$  \hspace{1cm} (77)\textsuperscript{89}

where:
- $F_{ax,d}$ is the axial load
- $F_{v,d}$ is the lateral load
- $R_{ax,d}$ is the axial design load-carrying capacity
- $R_{v,d}$ is the lateral design load-carrying capacity

10. FASTENER SPACINGS AND EDGE AND END DISTANCES

10.1 LATERALLY LOADED SCREWS - LOCATIONS PARALLEL TO THE GRAIN

For screws designed by part 5.1.

Due to the possibility of splitting it is recommended to stagger screws perpendicular to grain by at least $1d_f$. In this case the effective number of fasteners $n_{ef} = n$ may be used. In flatwise Kerto-Q connections screws do not need to be staggered.

For screwed connections the allowed tolerances according to Table 11.

10.2 LATERALLY LOADED SCREWS - FOR SCREWS $d \leq 8$ mm

This section does not apply for lag screws with diameter $6 \text{ mm} \leq d \leq 8$ mm, they are positioned according to 10.3. Predrilling is required if the characteristic density of the timber $\rho_0$ is greater than 500 kg/m$^3$ or the diameter of the smooth shank $d_s$ exceeds 6 mm. See more details at section 2.
Table 12: Minimum spacings and end and edge distances for flatwise screw connections, where nominal diameter of screw is not more than 8 mm. Symbols are illustrated in Figure 12 and Figure 13.

<table>
<thead>
<tr>
<th>Spacing or distance</th>
<th>Angle $\alpha$</th>
<th>Kerto-S</th>
<th>Kerto-Q</th>
<th>Kerto-S</th>
<th>Kerto-Q</th>
<th>Timber $\rho_k \leq 420 \text{ kg/m}^3$</th>
<th>Timber $420 \text{ kg/m}^3 &lt; \rho_k \leq 500 \text{ kg/m}^3$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spacing $a_1$ (parallel to grain)</td>
<td>$0^\circ \leq \alpha \leq 360^\circ$</td>
<td>$d_{ef} &lt; 5 \text{ mm}$: $d_{ef} \geq 5 \text{ mm}$:</td>
<td>$d_{ef} &lt; 5 \text{ mm}$:</td>
<td>$d_{ef} \geq 5 \text{ mm}$:</td>
<td>$d_{ef} &lt; 5 \text{ mm}$:</td>
<td>$d_{ef} \geq 5 \text{ mm}$:</td>
<td>$d_{ef} &lt; 5 \text{ mm}$:</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(5+7$</td>
<td>\cos \alpha</td>
<td>$)</td>
<td>(4+</td>
<td>$\cos \alpha</td>
<td>$)</td>
</tr>
<tr>
<td>Spacing $a_2$ (perpendicular to grain)</td>
<td>$0^\circ \leq \alpha \leq 360^\circ$</td>
<td>$5d_{ef}$</td>
<td>$5d_{ef}$</td>
<td>$5d_{ef}$</td>
<td>$7d_{ef}$</td>
<td>$5d_{ef}$</td>
<td>$3d_{ef}$</td>
</tr>
<tr>
<td>Distance $a_{1,1}$ (loaded end)</td>
<td>$-90^\circ \leq \alpha \leq 90^\circ$</td>
<td>$10d_{ef}$</td>
<td>$4d_{ef}$</td>
<td>$7d_{ef}$</td>
<td>$4d_{ef}$</td>
<td>$10d_{ef}$</td>
<td>$15d_{ef}$</td>
</tr>
<tr>
<td>Distance $a_{2,1}$ (unloaded end)</td>
<td>$-90^\circ \leq \alpha \leq 270^\circ$</td>
<td>$10d_{ef}$</td>
<td>$4d_{ef}$</td>
<td>$7d_{ef}$</td>
<td>$4d_{ef}$</td>
<td>$10d_{ef}$</td>
<td>$15d_{ef}$</td>
</tr>
<tr>
<td>Distances $a_{1,2}$ (loaded edge)</td>
<td>$0^\circ \leq \alpha \leq 180^\circ$</td>
<td>$d_{ef} &lt; 5 \text{ mm}$:</td>
<td>$d_{ef} \geq 5 \text{ mm}$:</td>
<td>$d_{ef} &lt; 5 \text{ mm}$:</td>
<td>$d_{ef} \geq 5 \text{ mm}$:</td>
<td>$d_{ef} &lt; 5 \text{ mm}$:</td>
<td>$d_{ef} \geq 5 \text{ mm}$:</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(5+2$</td>
<td>\sin \alpha</td>
<td>$)</td>
<td>(5+4$</td>
<td>\sin \alpha</td>
<td>$)</td>
</tr>
<tr>
<td>Distances $a_{2,2}$ (unloaded edge)</td>
<td>$180^\circ \leq \alpha \leq 360^\circ$</td>
<td>$d_{ef} &lt; 5 \text{ mm}$:</td>
<td>$d_{ef} \geq 5 \text{ mm}$:</td>
<td>$d_{ef} &lt; 5 \text{ mm}$:</td>
<td>$d_{ef} \geq 5 \text{ mm}$:</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>(5+4$</td>
<td>\sin \alpha</td>
<td>$)</td>
<td>(5+4$</td>
<td>\sin \alpha</td>
<td>$)</td>
</tr>
</tbody>
</table>

Figure 12: Minimum spacings and end and edge distances
This instruction is property of Metsä Wood. The instruction has been prepared in cooperation with VTT Expert Services Ltd.

Minimum screw spacings $a_1$ and $a_2$ for non-pre-drilled panel-to-timber flatwise and edgewise screwed connections are those given in Table 12 and Table 13 multiplied by a factor of 0.85. The minimum edge and end distances presented in Table 12 and Table 13 may not be reduced unless otherwise stated below.

Minimum edge $a_{4,c}$ and end distances $a_{3,c}$ in plywood members should be taken as $3d_{df}$ for an unloaded edge (or end) and $a_{4,e} = (3 + 4 \sin \alpha) d_{df}$ for a loaded edge (or end), where $\alpha$ is the angle between the direction of load and the loaded edge (or end). Minimum edge and end distances in other wood-based board are according to Table 12 and Table 13 unless board CE-mark otherwise states.

Minimum screw spacings $a_1$ and $a_2$ for non-predrilled steel-to-timber flatwise screw connection are those given in Table 12 multiplied by a factor of 0.70. The minimum edge and end distances presented in Table 12 may not be reduced for steel-to-timber connections.

---

**Table 13:** Minimum spacings and end and edge distances for edgewise Kerto screw connections, where nominal diameter of screw is not more than 8 mm. Symbols are illustrated in Figure 13.

<table>
<thead>
<tr>
<th>Spacing or distance</th>
<th>Angle $\alpha$</th>
<th>WITHOUT PRE-DRILLED HOLES</th>
<th>PREDRILLED HOLES</th>
</tr>
</thead>
<tbody>
<tr>
<td>$a_1$ (parallel to grain)</td>
<td>$0^\circ \leq \alpha \leq 360^\circ$</td>
<td>$(7+8</td>
<td>\cos \alpha</td>
</tr>
<tr>
<td>$a_2$ (perpendicular to grain)</td>
<td>$0^\circ \leq \alpha \leq 360^\circ$</td>
<td>$7d_{df}$</td>
<td>$1.4(3+</td>
</tr>
<tr>
<td>$a_{3,t}$ (loaded end)</td>
<td>$-90^\circ \leq \alpha \leq 90^\circ$</td>
<td>$(15+5\cos \alpha)d_{df}$</td>
<td>$1.4(7+5\cos \alpha)d_{df}$</td>
</tr>
<tr>
<td>$a_{3,c}$ (unloaded end)</td>
<td>$90^\circ \leq \alpha \leq 270^\circ$</td>
<td>$15d_{df}$</td>
<td>$9.8d_{df}$</td>
</tr>
<tr>
<td>$a_{4,t}$ (loaded edge)</td>
<td>$0^\circ \leq \alpha \leq 180^\circ$</td>
<td>$d_{df} \leq 5 \text{ mm}$: $(7+2\sin \alpha)d_{df}$</td>
<td>$d_{df} \leq 5 \text{ mm}$: $1.4(3+2\sin \alpha)d_{df}$</td>
</tr>
<tr>
<td>$a_{4,c}$ (unloaded edge)</td>
<td>$180^\circ \leq \alpha \leq 360^\circ$</td>
<td>$7d_{df}$</td>
<td>$4.2d_{df}$</td>
</tr>
</tbody>
</table>

---

Figure 13: Spacings and end and edge distances, (a) Spacing parallel to grain in a row and perpendicular to grain between rows, (b) Edge and end distances. (1) Loaded end, (2) Unloaded end, (3) Loaded edge, (4) Unloaded edge, 1 Fastener, 2 Grain direction.
10.3 LATERALLY LOADED SCREWS - FOR SCREWS $d > 8$ mm

This section applies also for lag screws with diameter $6$ mm $\leq d \leq 8$ mm. These screws are always predrilled. See more details at section 2.

The fastener spacing parallel to the grain $a_1$ and perpendicular to the grain $a_2$:

\[
\begin{align*}
-90^\circ & \leq \alpha \leq 90^\circ & 90^\circ & \leq \alpha \leq 270^\circ & 0^\circ & \leq \alpha \leq 180^\circ & 180^\circ & \leq \alpha \leq 360^\circ \\
\text{Loaded end} & & \text{Unloaded end} & & \text{Loaded end} & & \text{Unloaded end} \\
\end{align*}
\]

$\alpha$ is the angle between a force and the grain direction

**Figure 14:** Fastener spacings and edge and end distances. 97

**Table 14:** Screw minimum spacings and edge and end minimum distances. 98

<table>
<thead>
<tr>
<th>SPACING AND EDGE/END DISTANCE, SEE FIGURE 14</th>
<th>ANGLE</th>
<th>SOLID TIMBER AND GLUED LAMINATED TIMBER</th>
<th>KERTO-S, KERTO-T AND EDGewise KERTO-Q</th>
<th>FLATWISE KERTO-Q</th>
</tr>
</thead>
<tbody>
<tr>
<td>$a_1$</td>
<td>$0^\circ \leq \alpha \leq 360^\circ$</td>
<td>$(4+</td>
<td>\cos \alpha</td>
<td>)d_{ef}$</td>
</tr>
<tr>
<td>$a_2$</td>
<td>$0^\circ \leq \alpha \leq 360^\circ$</td>
<td>$4d_{ef}$</td>
<td>$4d_{ef}$</td>
<td>$4d_{ef}$</td>
</tr>
<tr>
<td>$a_{3,t}$</td>
<td>$-90^\circ \leq \alpha \leq 90^\circ$</td>
<td>max $(7d_{ef}; 80$ mm)</td>
<td>max $(7d_{ef}; 105$ mm)</td>
<td>max $(4d_{ef}; 60$ mm)</td>
</tr>
<tr>
<td>$a_{3,c}$</td>
<td>$90^\circ \leq \alpha \leq 150^\circ$</td>
<td>$(1+6\sin \alpha)d_{ef}$</td>
<td>$(1+6\sin \alpha)d_{ef}$</td>
<td>$4d_{ef}$</td>
</tr>
<tr>
<td></td>
<td>$150^\circ \leq \alpha \leq 210^\circ$</td>
<td>$4d_{ef}$</td>
<td>$4d_{ef}$</td>
<td>$4d_{ef}$</td>
</tr>
<tr>
<td></td>
<td>$210^\circ \leq \alpha \leq 270^\circ$</td>
<td>$(1+6</td>
<td>\sin \alpha</td>
<td>)d_{ef}$</td>
</tr>
<tr>
<td>$a_{4,t}$</td>
<td>$0^\circ \leq \alpha \leq 180^\circ$</td>
<td>max $((2+2\sin \alpha)d_{ef}; 3d_{ef})$</td>
<td>max $((2+2\sin \alpha)d_{ef}; 3d_{ef})$</td>
<td>max $((2+2\sin \alpha)d_{ef}; 3d_{ef})$</td>
</tr>
<tr>
<td>$a_{4,c}$</td>
<td>$180^\circ \leq \alpha \leq 360^\circ$</td>
<td>$3d_{ef}$</td>
<td>$3d_{ef}$</td>
<td>$3d_{ef}$</td>
</tr>
</tbody>
</table>

* Block shear should also be checked with timber-to-timber connections if $a_2 < 5d_{ef}$.
* For screws with effective diameter $d_{ef} < 15$ mm, the minimum end distance may be further reduced to $7d_{ef}$ if the embedment strength $f_{h,0,k}$ is reduced by factor $a_3/(105$ mm).
* For screws with effective diameter $d_{ef} < 15$ mm, the minimum end distance may be further reduced to $4d_{ef}$ if the embedment strength $f_{h,0,k}$ is reduced by factor $a_3/t/(60$ mm).
* The minimum spacing may be further reduced to $5d_{ef}$ if the embedment strength $f_{h,0,k}$ is reduced by factor $\frac{d_1}{\sqrt{(4+3|\cos \alpha|)}d_{ef}}$.
Table 15: For screwed moment resisting multi shear Kerto-to-Kerto flatwise connections with circular patterns of fasteners, the following minimum values of distances and spacings may be used.  

<table>
<thead>
<tr>
<th>SPACING AND EDGE/END DISTANCES</th>
<th>KERTO-S TO KERTO-Q</th>
<th>KERTO-S TO KERTO-S</th>
<th>KERTO-Q TO KERTO-Q</th>
</tr>
</thead>
<tbody>
<tr>
<td>End distance</td>
<td>$6d_{ef}$ in Kerto-S</td>
<td>$7d_{ef}$</td>
<td>$4d_{ef}$</td>
</tr>
<tr>
<td></td>
<td>$4d_{ef}$ in Kerto-Q</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Edge distance</td>
<td>$4d_{ef}$ in Kerto-S</td>
<td>$4d_{ef}$</td>
<td>$3d_{ef}$</td>
</tr>
<tr>
<td></td>
<td>$3d_{ef}$ in Kerto-Q</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Spacing on a circular</td>
<td>$5d_{ef}$</td>
<td>$6d_{ef}$</td>
<td>$4d_{ef}$</td>
</tr>
<tr>
<td>Spacing between circulars b)</td>
<td>$5d_{ef}$</td>
<td>$5d_{ef}$</td>
<td>$4d_{ef}$</td>
</tr>
</tbody>
</table>

* a) When Kerto-Q is used as outer member
* b) Between radius of the circulars

Figure 15: For screwed moment resisting multi shear Kerto-to-Kerto flatwise connections with circular patterns of fasteners.
10.4 AXIALLY LOADED SCREWS

Minimum spacings and end and edge distances for axially loaded screws, should be taken from Table 16 to Table 19, provided that the timber thickness \( t \geq 12d \).

**Table 16: Minimum spacings and edge and end distances for axially loaded screws for solid timber, glued laminated timber and flatwise Kerto.**

<table>
<thead>
<tr>
<th>Minimum screw spacing in a plane parallel to the grain</th>
<th>Minimum screw spacing perpendicular to a plane( a_1 ) parallel to the grain</th>
<th>Minimum end distance of the centre of the gravity of the threaded part of the screw in the member</th>
<th>Minimum edge distance of the centre of the gravity of the threaded part of the screw in the member</th>
</tr>
</thead>
<tbody>
<tr>
<td>7d</td>
<td>5d</td>
<td>10d</td>
<td>4d</td>
</tr>
</tbody>
</table>

**Table 17: Minimum spacings and edge and end distances for axially loaded self-drilling Würth Assy plus, Würth Assy plus VG, SFS Intec WT-T and pre-drilled self-tapping screws for flatwise Kerto.**

<table>
<thead>
<tr>
<th>Minimum screw spacing in a plane parallel to the grain</th>
<th>Minimum screw spacing perpendicular to a plane( a_1 ) parallel to the grain</th>
<th>Minimum end distance of the centre of the gravity of the threaded part of the screw in the member</th>
<th>Minimum edge distance of the centre of the gravity of the threaded part of the screw in the member</th>
</tr>
</thead>
<tbody>
<tr>
<td>7d</td>
<td>5d</td>
<td>10d</td>
<td>3d</td>
</tr>
</tbody>
</table>

**Table 18: Minimum spacings and edge and end distances for axially loaded self-tapping and self-drilling screws for edgewise Kerto, where screws are parallel to the plane of veneers and perpendicular to the grain direction of face veneers.**

<table>
<thead>
<tr>
<th>Minimum screw spacing in a plane parallel to the grain</th>
<th>Minimum screw spacing perpendicular to a plane( a_1 ) parallel to the grain</th>
<th>Minimum end distance of the centre of the gravity of the threaded part of the screw in the member</th>
<th>Minimum edge distance of the centre of the gravity of the threaded part of the screw in the member</th>
</tr>
</thead>
<tbody>
<tr>
<td>10d</td>
<td>5d</td>
<td>12d</td>
<td>4d</td>
</tr>
</tbody>
</table>

**Table 19: Minimum spacings and edge and end distances for axially loaded self-drilling Würth Assy plus, Würth Assy plus VG, SFS Intec WT-T and pre-drilled self-tapping screws for edgewise Kerto, where screws are parallel to the plane of veneers and perpendicular to the grain direction of face veneers.**

<table>
<thead>
<tr>
<th>Minimum screw spacing in a plane parallel to the grain</th>
<th>Minimum screw spacing perpendicular to a plane( a_1 ) parallel to the grain</th>
<th>Minimum end distance of the centre of the gravity of the threaded part of the screw in the member</th>
<th>Minimum edge distance of the centre of the gravity of the threaded part of the screw in the member</th>
</tr>
</thead>
<tbody>
<tr>
<td>10d</td>
<td>5d</td>
<td>12d</td>
<td>3d</td>
</tr>
</tbody>
</table>
Generally the penetration depth of the threaded part in point side timber should be at least 6d. For Kerto-Kate boards and Metsä Wood Spruce plywood, 3d may be used as the minimum penetration depth of the threaded length for lateral and axial loads. For flatwise Kerto-Q, a 3.5d may be used as the minimum penetration depth of the threaded length for axial loads if the conical part of the point side of the screw entirely penetrates through the Kerto-Q.

11. ALLOWED TOLERANCES OF SCREWED CONNECTIONS

<table>
<thead>
<tr>
<th>Screwed timber-to-timber connection</th>
<th>Fastener position</th>
<th>Fastener spacing a₁ and a₂</th>
<th>±a₁ / ±a₂</th>
</tr>
</thead>
<tbody>
<tr>
<td>Head flush</td>
<td>To timber surface</td>
<td>±0 / ±3 mm</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Screwed steel-to-timber connection</th>
<th>Hole location</th>
<th>Holes in steel plate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inclined screwing</td>
<td>Screwing angle</td>
<td>±5º</td>
</tr>
</tbody>
</table>

*a* Screws in row parallel to grain should be staggered perpendicular to the grain by at least 1d_{elf} if a₁ is less than 14d_{elf}.

12. BIBLIOGRAPHY

6. VTT-S-04222-11, Eurokoodi 5 ruuvimitoitusohjeiden soveltaminen Kerto-Kate levylle, Finnforest Spruce vanerille sekä Kerto-Q-LVL:lle.
CHECKING THE POSSIBILITY OF USING 4X60 SCREW

\[ d_i = 2.50 \text{ mm (from manufacturer)} \]
\[ d_{ef} = 1.1d_i = 2.75 \text{ mm} \]
\[ d_i = 2.90 \text{ mm (from manufacturer)} \]
\[ M_{f,k} = 2800 \text{ Nmm (from manufacturer)} \]
\[ l_k = 34 \text{ mm, threaded part (from manufacturer)} \]

PRE-DRILLING

\[ d \leq 8 \text{ mm and } d_i \leq 6 \text{ mm} \]
\[ \rho_i \leq 500 \text{ kg/m}^3 \text{ (Kerto-S 480 kg/m}^3) \]

pre-drilling is not needed.

PENETRATION DEPTH

\[ t_1 = 27 \text{ mm} > 8d_{ef} = 22 \text{ mm} \]
\[ t_2 = 60 \text{ mm} - 27 \text{ mm} = 33 \text{ mm} > 12d_{ef} = 30 \text{ mm} \]

\[ k_t = \max \left( 1 + 0.3 \cdot \frac{t_1 - 8d_{ef}}{8d_{ef}}, 1 + 0.3 \cdot \frac{t_2 - 12d_{ef}}{6d_{ef}} \right) = 1.06 \]

\[ k_t \leq \frac{M_f}{160d_{ef}^{2.6}} = \sqrt{\frac{2800}{160 \cdot 2.75^{2.6}}} = 1.12 \]

\[ R_k = 120 \cdot d_i^{0.7} = 669 \text{ N} \]
\[ k_{mod} = 0.8, \gamma_M = 1.2 \text{ (Kerto-S)} \]

\[ R_d = \frac{k_{mod} \cdot k_{p} \cdot k_t \cdot R_k}{\gamma_M} = \frac{0.8 \cdot 480}{350} \cdot 1.10 \cdot 669 \text{ N} = 553 \text{ N} \]

REQUIRED AMOUNT OF SCREWS

\[ n = \frac{F_{v,d}}{R_d} = \frac{25.6 \text{kN} / 2}{0.553 \text{kN}} = 23.2 \]

27 pieces of 4 x 60 screws for each side of the connection is selected.

SCREW POSITIONING

With Kerto-S the screws are be staggered by \( d \). Screws are positioned to the compressed side of the rafter. With these rules the risks of splitting is avoided. See Figure 19 and Figure 20.

Screw spacing in tension member \( a_i \):

- tension member (\( \alpha = 0 \))
  \[ a_i \geq a_{i,min} = (5 + 5 \cos \alpha) d_{ef} = 27.5 \text{ mm} \]

- main rafter
  \[ a_i \geq a_{2,min} / \sin 22^\circ = 5d_{ef} / \sin 22^\circ = 36.7 \text{ mm} \]

\( a_i = 40 \text{ mm} \) is chosen.

Screw spacing in main rafter \( a_p \):

- tension member
  \[ a_p \geq a_{2,min} / \sin 22^\circ = 5d_{ef} / \sin 22^\circ = 36.7 \text{ mm} \]

- main rafter (\( \alpha = 22^\circ \))
  \[ a_p \geq a_{1,min} = (5 + 5 \cos \alpha) d_{ef} = 26.5 \text{ mm} \]

\( a_p = 40 \text{ mm} \) is chosen, in this case the tension members perpendicular direction \( a_p = 15 \text{ mm} \) (\( = 40 \text{ mm sin } 22^\circ \))

END DISTANCE IN THE TENSION MEMBER

- tension member (\( \alpha = 0 \))
  \[ a_{3,min} = (10 + 5 \cos \alpha) d_{ef} = 41.3 \text{ mm} \]
  50 mm is chosen

EDGE DISTANCES

- main rafter, loaded edge
  \[ a_{4,l} \geq (5 + 2 \sin \alpha) d_{ef} = 15.9 \text{ mm (} \alpha = 158^\circ \) \]
  \[ a_{4,l} = 204 \text{ mm is chosen} \]

- other edges
  \[ a_{4,c} \geq 5d_{ef} = 13.75 \text{ mm} \]

- tension member
  \[ a_{4,c} = 40 \text{ mm is chosen} \]

- main rafter upped edge
  \[ a_{4,c} = 168 \text{ mm chosen} \]
CALCULATION EXAMPLE: AXIALLY LOADED STEEL-TO-TIMBER SCREW CONNECTION

A cable rack is installed to the lower surface of roof element with self-weight 40 kg/m. Suspension connections are c/c 2.5 m crosswise to roof element. Suspension connections are done to Kerto-S edge.
Load combinations

\[
P_d = 1.35 \cdot 2.5m \cdot 0.4kN / m = 1.35kN
\]

CHECKING THE POSSIBILITY OF USING 5X90 SCREW AND REQUIRED AMOUNT

PRE-DRILLING

\[
d \leq 8 \text{ mm and } d_s \leq 6 \text{ mm}
\]
\[
\rho_k \leq 500 \text{ kg/m}^3 \text{ (Kerto-S 480 kg/m}^3\text{)}
\]

pre-drilling is not needed.

THE CHARACTERISTIC LOAD-CARRYING CAPACITY OF EDGewise KerTo-S CONNECTION

\[
F_{ax,Rk} = n^{0.9} \cdot f_{ax,k} \cdot d \cdot l_{ef}
\]

where:\n\[
d \text{ is the outer threaded diameter, in mm}
\]
\[
f_{ax,k} = 10 \text{ N/mm}^2
\]
\[
n \text{ is the number of screws acting together in a connection}
\]
\[
l_{ef} \text{ is the penetration length of the threaded part, 50 mm (55 mm - d)}
\]

THE CHARACTERISTIC LOAD-CARRYING CAPACITY

\[
F_{ax,Rk} = 2.50 \text{ kN for single screw}
\]
\[
F_{ax,Rk} = 4.66 \text{ kN for two screws}
\]

THE DESIGN LOAD-CARRYING CAPACITY

\[
R_d = \frac{k_{mod}}{\gamma_M} F_{ax,Rk}
\]

where:\n\[
k_{mod} = 0.6 \text{ (permanent action), } \gamma_M = 1.2 \text{ (Kerto-S)}
\]
\[
R_d = 1.25 \text{ kN for single screw}
\]
\[
R_d = 2.33 \text{ kN for two screws}
\]

Two screw connection is selected 2.33kN >1.35 kN

The characteristic tensile resistance of the connection (head tear-off or tensile capacity of shank), should be taken as:

\[
F_{t,Rk} = n_{ef} \cdot f_{tens,k}
\]

where: \( f_{tens,k} \) is the characteristic tensile capacity of the screw determined in accordance with EN 14592. It can be calculated using the minimum tensile strength \( f_{u,k} = 500 \text{ N/mm}^2 \) and the minimum inner threaded diameter \( 0.6d \):

\[
f_{tens,k} = f_{u,k} \cdot \pi \cdot \left( \frac{1.1 \cdot 0.6d}{2} \right)^2
\]

\( n_{ef} \) is the effective number of screws

\[
F_{t,Rk} = 7.98 \text{ kN for two screws}
\]

\[
F_{t,Rd} = \frac{F_{R,k}}{\gamma_{M2}}
\]

where: \( \gamma_{M2} = 1.25 \text{ for steel} \)

\[
F_{t,Rd} = 6.38 \text{ kN > 1.35 kN}
\]

SCREW SPACING AND END AND EDGE DISTANCES

Spacing (minimum):
\[
a_1 = 10d = 50.0 \text{ mm parallel to the grain}
\]

END DISTANCE (MINIMUM)

\[
a_3 = 12d = 60.0 \text{ mm}
\]

EDGE DISTANCE (MINIMUM)

\[
a_4 = 4d = 20.0 \text{ mm Kerto-S 51 mm is wide enough}
\]

PENETRATION DEPTH (MINIMUM)

\[
l_{ef} = 50 \text{ mm > } 6d = 30 \text{ mm}
\]