Tension joint

SPLICE TENSION JOINT ON A TRUSS CHORD
Example

Design a splice tension joint using the following data:

- tensile force [kN]:
  30 40 50 60 70 80 90 100 110 120 130 140 150 160

- strength class of timber: C14 C16 C20 C22 C24 C27 C30 C35

- fasteners: Dowels
  *Dowels of class 5.8 (char. tensile strength: $f_{u,k}=500$ Mpa)*

- factor $k_{mod}$: 0.50 0.55 0.60 0.65 0.70 0.80 0.90 1.10
CHOISE OF JOINT MEMBERS
Choice of joint type

Small tensile forces or high strength class of timber:

Big tensile forces or low strength class of timber:
The correct scale drawing can be found in a separate pdf file.
# Strength classes of timber

<table>
<thead>
<tr>
<th>Strength properties (in N/mm²)</th>
<th>Softwood species</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>C14</td>
</tr>
<tr>
<td>Bending</td>
<td>fₘₖ</td>
</tr>
<tr>
<td>Tension parallel</td>
<td>fₜ₀ₖ</td>
</tr>
<tr>
<td>Tension perpendicular</td>
<td>f₁₈₀ₖ</td>
</tr>
<tr>
<td>Compression parallel</td>
<td>fₖ₀ₖ</td>
</tr>
<tr>
<td>Compression perpendicular</td>
<td>f₉₀₆₀ₖ</td>
</tr>
<tr>
<td>Shear</td>
<td>fₖ₉₀ₖ</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Stiffness properties (in kN/mm²)</th>
<th>Softwood species</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean modulus of elasticity parallel</td>
<td>E₀,mean</td>
</tr>
<tr>
<td>5% modulus of elasticity parallel</td>
<td>E₀,05</td>
</tr>
<tr>
<td>Mean modulus of elasticity perpendicular</td>
<td>E₉₀,mean</td>
</tr>
<tr>
<td>Mean shear modulus</td>
<td>Gₘₑₙ</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Density (in kg/m³)</th>
<th>Softwood species</th>
</tr>
</thead>
<tbody>
<tr>
<td>Density</td>
<td>ρₓ</td>
</tr>
<tr>
<td>Mean density</td>
<td>ρₘₑₙ</td>
</tr>
</tbody>
</table>
2.4.1 Design value of material property

(1)P The design value $X_d$ of a strength property shall be calculated as:

$$X_d = k_{mod} \frac{X_k}{\gamma_M}$$  \hspace{1cm} (2.14)

where:

- $X_k$ is the characteristic value of a strength property;
- $\gamma_M$ is the partial factor for a material property;
- $k_{mod}$ is a modification factor taking into account the effect of the duration of load and moisture content.

NOTE 1: Values of $k_{mod}$ are given in 3.1.3.

NOTE 2: The recommended partial factors for material properties ($\gamma_M$) are given in Table 2.3. Information on the National choice may be found in the National annex.
Material factor

Table 2.3 – Recommended partial factors $\gamma_M$ for material properties and resistances

<table>
<thead>
<tr>
<th>Fundamental combinations</th>
<th>1,3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solid timber</td>
<td>1,3</td>
</tr>
<tr>
<td>Glued laminated timber</td>
<td>1,25</td>
</tr>
<tr>
<td>LVL, plywood, OSB</td>
<td>1,2</td>
</tr>
<tr>
<td>Particleboards</td>
<td>1,3</td>
</tr>
<tr>
<td>Fibreboards, hard</td>
<td>1,3</td>
</tr>
<tr>
<td>Fibreboards, medium</td>
<td>1,3</td>
</tr>
<tr>
<td>Fibreboards, MDF</td>
<td>1,3</td>
</tr>
<tr>
<td>Fibreboards, soft</td>
<td>1,3</td>
</tr>
<tr>
<td>Connections</td>
<td>1,3</td>
</tr>
<tr>
<td>Punched metal plate fasteners</td>
<td>1,25</td>
</tr>
<tr>
<td>Accidental combinations</td>
<td>1,0</td>
</tr>
</tbody>
</table>
Design strength

Design tensile strength along the grain:

\[ f_{t,0,d} = \frac{k_{\text{mod}} f_{t,0,k}}{\gamma_M} = \frac{0,8 \cdot 18}{1,3} = 11,08 \, MPa \]
Selection of cross-sections of joint members

FIRST CONDITION OF SELECTION

- minimum cross-section of the chord needed to carry the given tensile force:

$$\sigma_{t,0,d} \leq f_{t,0,d}$$

$$\frac{N}{A_{netto}} \leq f_{t,0,d}$$

$$A_{netto} = \beta \cdot A_{tot}$$

$$\frac{N}{\beta \cdot A_{tot}} \leq f_{t,0,d}$$

$$A_{tot} \geq \frac{N}{\beta \cdot f_{t,0,d}}$$

* loss in cross-sectional area of the joint due to fasteners is estimated at 15% ($\beta = 85\%$)

$$A_{tot} \geq \frac{100}{0.85 \cdot 1.108} = 106,18 \text{ cm}^2$$
Selection of cross-sections of joint members

SECOND CONDITION OF SELECTION

- minimum width $h$ of the chord elements (assumed number of rows $n_r$ and diameter of fasteners $d$):

$$h \geq (n_r - 1) \cdot a_2 + 2a_{4,c}$$

- $a_2$ – fasteners spacing perpendicular to grain
- $a_{4,c}$ – distance from the unloaded edge
Fasteners spacings and distances

Figure 8.7 – 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
### 8.6 Dowelled connections

(1) The rules given in 8.5.1 except 8.5.1.1(3) apply.

(2) The dowel diameter should be greater than 6 mm and less than 30 mm.

(3) Minimum spacing and edge and end distances are given in Table 8.5, with symbols illustrated in Figure 8.7.

#### Table 8.5 – Minimum spacings and edge and end distances for dowels

<table>
<thead>
<tr>
<th>Spacing and edge/end distances (see Figure 8.7)</th>
<th>Angle</th>
<th>Minimum spacing or edge/end distance</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\alpha_1$ (parallel to grain)</td>
<td>$0 ^\circ \leq \alpha \leq 360 ^\circ$</td>
<td>$(3 + 2 \mid \cos \alpha \mid \cdot d)$</td>
</tr>
<tr>
<td>$\alpha_2$ (perpendicular to grain)</td>
<td>$0 ^\circ \leq \alpha \leq 360 ^\circ$</td>
<td>$3 \cdot d$</td>
</tr>
<tr>
<td>$\alpha_{3,t}$ (loaded end)</td>
<td>$-90 ^\circ \leq \alpha \leq 90 ^\circ$</td>
<td>max $(7 \cdot d; 80 \text{ mm})$</td>
</tr>
<tr>
<td>$\alpha_{3,c}$ (unloaded end)</td>
<td>$90 ^\circ \leq \alpha &lt; 150 ^\circ$</td>
<td>max$(\alpha_{3,t} \mid \sin \alpha \mid \cdot d; 3d)$</td>
</tr>
<tr>
<td></td>
<td>$150 ^\circ \leq \alpha &lt; 210 ^\circ$</td>
<td>$3 \cdot d$</td>
</tr>
<tr>
<td></td>
<td>$210 ^\circ \leq \alpha \leq 270 ^\circ$</td>
<td>max$(\alpha_{3,t} \mid \sin \alpha \mid \cdot d; 3d)$</td>
</tr>
<tr>
<td>$\alpha_{4,t}$ (loaded edge)</td>
<td>$0 ^\circ \leq \alpha \leq 180 ^\circ$</td>
<td>max$(2 + 2 \sin \alpha \cdot d; 3d)$</td>
</tr>
<tr>
<td>$\alpha_{4,c}$ (unloaded edge)</td>
<td>$180 ^\circ \leq \alpha \leq 360 ^\circ$</td>
<td>$3 \cdot d$</td>
</tr>
</tbody>
</table>
SECOND CONDITION OF SELECTION

- 2 rows of fasteners φ12 assumed (the dowel diameter should be chosen in such a way, that it is possible to adopt the bolts of the same diameter):

\[
h \geq (n_r - 1) \cdot a_2 + 2a_{4,c} = (n_r - 1) \cdot 3d + 2 \cdot 3d
\]

\[
h \geq (2 - 1) \cdot 3 \cdot 12 + 2 \cdot 3 \cdot 12 = 108 \text{ mm}
\]
Selection of cross-sections of joint members

Cross-sectional area of the chord must satisfy two conditions:

\[ A_{tot} \geq 106,18 \, cm^2 \rightarrow 2 \cdot b_{ch} \cdot h \geq 106,18 \, cm^2 \]

\[ h \geq 108 \, mm \]

Recommended thickness of the central member:

\[ b_{cm} = b_{ch} \]

Recommended thickness of side members:

\[ b_{sm} = 0,75 b_{ch} \]
Selection of cross-sections of joint members

Assumed cross-sections:

- chord: \(2 \times 50 \times 125\)
- central member: \(50 \times 125\)
- side members: \(2 \times 38 \times 125\)

* cross-sections were assumed basing on the timber assortment table
Customary target sizes of timber in Poland

<table>
<thead>
<tr>
<th>NAME</th>
<th>Thickness (mm)</th>
<th>Width (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boards</td>
<td>19 75</td>
<td>100 115</td>
</tr>
<tr>
<td></td>
<td>22 75</td>
<td>125 140</td>
</tr>
<tr>
<td></td>
<td>25 75</td>
<td>125 140</td>
</tr>
<tr>
<td></td>
<td>32 75</td>
<td>125 140</td>
</tr>
<tr>
<td></td>
<td>38 100</td>
<td>125 140</td>
</tr>
<tr>
<td></td>
<td>45 100</td>
<td>125 140</td>
</tr>
<tr>
<td>Planks</td>
<td>50 100</td>
<td>125 140</td>
</tr>
<tr>
<td></td>
<td>63 115</td>
<td>125 140</td>
</tr>
<tr>
<td></td>
<td>75 115</td>
<td>125 140</td>
</tr>
<tr>
<td></td>
<td>100 125</td>
<td>125 140</td>
</tr>
<tr>
<td>Laths</td>
<td>38 50 100</td>
<td>125 140</td>
</tr>
<tr>
<td></td>
<td>45 63 100</td>
<td>125 140</td>
</tr>
<tr>
<td></td>
<td>45 63 75</td>
<td>125 140</td>
</tr>
<tr>
<td></td>
<td>75 75</td>
<td>125 140</td>
</tr>
<tr>
<td>Sawn timber</td>
<td>100 100</td>
<td>125 140</td>
</tr>
<tr>
<td></td>
<td>125 125</td>
<td>125 140</td>
</tr>
<tr>
<td></td>
<td>150 125</td>
<td>125 140</td>
</tr>
<tr>
<td></td>
<td>175 125</td>
<td>125 140</td>
</tr>
<tr>
<td>Beams</td>
<td>200 100</td>
<td>200 225</td>
</tr>
<tr>
<td></td>
<td>250 100</td>
<td>250 275</td>
</tr>
</tbody>
</table>

Lengths:
- boards, planks, laths: 2,40 – 6,30 m co 0,30 m i 0,90 – 2,30 m co 0,10 m
- sawn timber: 2,40 – 6,30 m co 0,30 m
- beams: 3,00 – 6,30 m co 0,30 m
STRESSES IN JOINT MEMBERS
Forces in the joint

forces in side members should be increased by 50% due to the eccentricity of the force $N$.
Forces in the joint

forces in side members should be increased by 50% due to the eccentricity of the force $N$
Stresses check

- **Chord:**
  \[
  \sigma_{ch} = \frac{N}{2} \cdot \frac{2}{A_{netto, ch}} = \frac{N}{2} \cdot \frac{2}{2b_{ch} (h - 2d)} = \frac{100000}{2 \cdot 50 \cdot (125 - 2 \cdot 12)} = 9,90 \text{ MPa} < f_{t,0,d} = 11,08 \text{ MPa}
  \]
  \(\sim 80\%-90\% \text{ of } f_{t,0,d}\)

- **Central member:**
  \[
  \sigma_{cm} = \frac{N}{2} \cdot \frac{2}{A_{netto, cm}} = \frac{N}{2} \cdot \frac{2}{b_{cm} (h - 2d)} = \frac{50000}{50 \cdot (125 - 2 \cdot 12)} = 9,90 \text{ MPa} < f_{t,0,d} = 11,08 \text{ MPa}
  \]
  \(\sim 80\%-90\% \text{ of } f_{t,0,d}\)

- **Side members:**
  \[
  \sigma_{sm} = \frac{1,5 \cdot N}{2} \cdot \frac{2}{A_{netto, sm}} = \frac{1,5 \cdot N}{2} \cdot \frac{2}{2b_{sm} (h - 2d)} = \frac{1,5 \cdot 50000}{2 \cdot 38 \cdot (125 - 2 \cdot 12)} = 9,77 \text{ MPa} < f_{t,0,d} = 11,08 \text{ MPa}
  \]
  \(\sim 80\%-90\% \text{ of } f_{t,0,d}\)
3

NUMBER OF FASTENERS
Failure modes for timber connections

Key:
(1) Single shear
(2) Double shear

NOTE: The letters correspond to the references of the expressions (8.6) and (8.7)

Figure 8.2 – Failure modes for timber and panel connections.
8.1.3 Multiple shear plane connections

(1) In multiple shear plane connections the resistance of each shear plane should be determined by assuming that each shear plane is part of a series of three-member connections.

8.2.2 Timber-to-timber and panel-to-timber connections

(1) The characteristic load-carrying capacity for nails, staples, bolts, dowels and screws per shear plane per fastener, should be taken as the minimum value found from the following expressions:

- For fasteners in double shear:

\[
F_{v,\text{Rk}} = \min \left\{ \begin{array}{l}
0.5 f_{h,2,k} t_2 d \\
1.05 \frac{f_{h,1,k} t_1 d}{2 + \beta} \left[ \frac{4 \beta (2 + \beta) M_{y,\text{Rk}}}{f_{h,1,k} d t_1^2} - \beta \right] + \frac{F_{\text{ax,}\text{Rk}}}{4} \\
1.15 \sqrt{\frac{2 \beta}{1 + \beta}} \sqrt{2 M_{y,\text{Rk}} f_{h,1,k} d} + \frac{F_{\text{ax,}\text{Rk}}}{4}
\end{array} \right. \tag{8.7}
\]

with

\[
\beta = \frac{f_{h,2,k}}{f_{h,1,k}} \tag{8.8}
\]
Load-carrying capacity of fasteners

where:

\( F_{v,Rk} \) is the characteristic load-carrying capacity per shear plane per fastener;

\( t_i \) is the timber or board thickness or penetration depth, with \( i \) either 1 or 2, see also 8.3 to 8.7;

\( f_{h,i,k} \) is the characteristic embedment strength in timber member \( i \);

\( d \) is the fastener diameter;

\( M_{y,Rk} \) is the characteristic fastener yield moment;

\( \beta \) is the ratio between the embedment strength of the members;

\( F_{ax,Rk} \) is the characteristic axial withdrawal capacity of the fastener, see (2).
Load-carrying capacity of fasteners

8.6 Dowelled connections

(1) The rules given in 8.5.1 except 8.5.1.1(3) apply.

(2) The dowel diameter should be greater than 6 mm and less than 30 mm.

(3) Minimum spacing and edge and end distances are given in Table 8.5, with symbols illustrated in Figure 8.7.
8.5 Bolted connections

8.5.1 Laterally loaded bolts

8.5.1.1 General and bolted timber-to-timber connections

(1) For bolts the following characteristic value for the yield moment should be used:

\[ M_{y,Rk} = 0.3 f_{u,k} d^{2.6} \]  \hspace{1cm} (8.30)

where:

- \( M_{y,Rk} \) is the characteristic value for the yield moment, in Nmm;
- \( f_{u,k} \) is the characteristic tensile strength, in N/mm²;
- \( d \) is the bolt diameter, in mm.

(2) For bolts up to 30 mm diameter, the following characteristic embedment strength values in timber and LVL should be used, at an angle \( \alpha \) to the grain:

\[ f_{h,\alpha,k} = \frac{f_{h,0,k}}{k_0 \sin^2 \alpha + \cos^2 \alpha} \]

\[ f_{h,0,k} = 0.082 (1 - 0.01 d) \rho_k \]

- \( f_{h,0,k} \) is the characteristic embedment strength parallel to grain, in N/mm²;
- \( \rho_k \) is the characteristic timber density, in kg/m³;
- \( \alpha \) is the angle of the load to the grain;
- \( d \) is the bolt diameter, in mm.
Load-carrying capacity of fasteners

Characteristic embedment strength parallel to grain:

\[ f_{h,0,k} = f_{h,1,k} = f_{h,2,k} = 0.082(1 - 0.01d)\rho_k \]
\[ f_{h,0,k} = 0.082(1 - 0.01 \cdot 12) \cdot 380 = 27.42 \text{ MPa} \]

Characteristic value for the yield moment:

\[ M_{y,Rk} = 0.3 f_{u,k} d^{2.6} = 0.3 \cdot 500 \cdot 12^{2.6} = 95932 \text{ Nmm} \]

The same class of timber used for all joint members, therefore:

\[ \beta = \frac{f_{h,2,k}}{f_{h,1,k}} = 1 \]
Load-carrying capacity of fasteners

Characteristic load-carrying capacity per shear plane per fastener:

\[
f_{h,1,k} t_1 d = 27,42 \cdot 38 \cdot 12 = 12500 \text{ N}
\]

\[
0,5 f_{h,2,k} t_2 d = 0,5 \cdot 27,42 \cdot 50 \cdot 12 = 8230 \text{ N}
\]

\[
F_{v,Rk} = \min \left\{ 1,05 \frac{f_{h,1,k} t_1 d}{2 + \beta} \left[ \sqrt{2 \beta (1 + \beta) + \frac{4 \beta (2 + \beta) M_{y,Rk}}{f_{h,1,k} dt_1^2}} - \beta \right] = \\
= 1,05 \frac{27,42 \cdot 38 \cdot 12}{2 + 1} \left[ \sqrt{2 \cdot 1 \cdot (1 + 1) + \frac{4 \cdot 1 \cdot (2 + 1) \cdot 95932}{27,42 \cdot 12 \cdot 38^2}} - 1 \right] = 6710 \text{ N} \right. \]

\[
1,15 \sqrt{\frac{2 \beta}{1 + \beta}} \sqrt{2 M_{y,Rk} f_{h,1,k} d} = 1,15 \sqrt{\frac{2 \cdot 1}{1 + 1}} \sqrt{2 \cdot 95932 \cdot 27,42 \cdot 12} = 9130 \text{ N}
\]
Load-carrying capacity of fasteners

Characteristic load-carrying capacity of a fastener in double shear per shear plane:

\[ F_{v,Rk} = 6,71 \text{kN} \]

Design load-carrying capacity of a fastener in double shear per shear plane:

\[ F_{v,Rd} = \frac{k_{\text{mod}} F_{v,Rk}}{\gamma_{M}} = \frac{0,8 \cdot 6,71}{1,3} = 4,13 \text{kN} \]
Determination of the number of fasteners

Total number of fasteners needed:

\[ n_{tot} \geq \frac{n}{n_{ef} n_{c} F_{v,Rd}} N \]

where:

- \( n \) – number of fasteners in one row
- \( n_{ef} \) – effective number of fasteners in one row
- \( n / n_{ef} \) – assumed 1,2 for the first iteration – after initial calculation, the real values should be inserted
- \( n_{c} \) – number of shear planes

\[ n_{tot} \geq 1,2 \cdot \frac{100}{4 \cdot 4,13} = 7,26 \quad \rightarrow \quad n_{tot} = 8 \]
Determination of the number of fasteners

8 fasteners in two rows assumed
Spacing parallel to grain \( a_1 = 10d = 12 \text{ cm} (a_{1,\min} = 5d) \)

Table 8.5 – Minimum spacings and edge and end distances for dowels

<table>
<thead>
<tr>
<th>Spacing and edge/end distances (see Figure 8.7)</th>
<th>Angle</th>
<th>Minimum spacing or edge/end distance</th>
</tr>
</thead>
<tbody>
<tr>
<td>( a_1 ) (parallel to grain)</td>
<td>( 0^\circ \leq \alpha \leq 360^\circ )</td>
<td>( (3 + 2</td>
</tr>
<tr>
<td>( a_2 ) (perpendicular to grain)</td>
<td>( 0^\circ \leq \alpha \leq 360^\circ )</td>
<td>( 3 \ d )</td>
</tr>
<tr>
<td>( a_{3,\text{l}} ) (loaded end)</td>
<td>( -90^\circ \leq \alpha \leq 90^\circ )</td>
<td>( \max(7 \ d; 80 \text{ mm}) )</td>
</tr>
</tbody>
</table>
| \( a_{3,\text{c}} \) (unloaded end)            | \( 90^\circ \leq \alpha < 150^\circ \)  
                             \( 150^\circ \leq \alpha < 210^\circ \)  
                             \( 210^\circ \leq \alpha \leq 270^\circ \) | \( \max(\alpha_{3,\text{l}} \ |\sin \alpha| \ d; 3d) \)  
                             \( 3 \ d \)  
                             \( \max(\alpha_{3,\text{l}} \ |\sin \alpha| \ d; 3d) \) |
| \( a_{4,\text{l}} \) (loaded edge)             | \( 0^\circ \leq \alpha \leq 180^\circ \) | \( \max([2 + 2 \sin \alpha] \ d; 3d) \) |
| \( a_{4,\text{c}} \) (unloaded edge)           | \( 180^\circ \leq \alpha \leq 360^\circ \) | \( 3 \ d \) |
(4) For one row of \( n \) bolts parallel to the grain direction, the load-carrying capacity parallel to grain, see 8.1.2(4), should be calculated using the effective number of bolts \( n_{ef} \) where:

\[
n_{ef} = \min \left\{ n, n^{0.9} \sqrt[4]{\frac{a_1}{13d}} \right\}
\]

where:

\( a_1 \) is the spacing between bolts in the grain direction;

\( d \) is the bolt diameter

\( n \) is the number of bolts in the row.
Load-carrying capacity for the group of fasteners

Effective number of fasteners in one row:

\[ n_{ef} = \min \left\{ n, \frac{4}{n^{0.9}} \frac{\sqrt{a_1}}{13d} \right\} = \left\{ 4, \frac{4^{0.9}}{\sqrt{10d}} \frac{10d}{13d} = 3.26 \rightarrow n_{ef} = 3.26 \right\} \]

Design load-carrying capacity for the group of fasteners:

\[ N_{tot} = n_{ef} n_r n_c F_{v,Rd} = 3.26 \cdot 2 \cdot 4 \cdot 4.13 = 107.71 \text{kN} > N = 100 \text{kN} \]

~80÷90% of \( N_{tot} \)
Draw bolts

Minimum number of draw bolts:

\[
n_s = \max \left\{ \frac{3}{25\% n_{tot}} \right\} = \max \left\{ \frac{3}{2} = 3 \right\}
\]

Three draw bolts at each side of the joint assumed

The diameter of bolts should be the same as for the dowels
CONFIGURATION AND CHARACTERISTICS OF FASTENERS
# Fasteners spacings and distances

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Minimum distance</th>
<th>Assumed distance</th>
</tr>
</thead>
<tbody>
<tr>
<td>$a_1$</td>
<td>$5d=60 \text{ mm}$</td>
<td>120 mm</td>
</tr>
<tr>
<td>$a_2$</td>
<td>dowels: $3d=36 \text{ mm}$ *bolts: $4d=48 \text{ mm}$</td>
<td>53 mm</td>
</tr>
<tr>
<td>$a_{3,t}$</td>
<td>$\max(7d, 80 \text{ mm})=84 \text{ mm}$</td>
<td>90 mm</td>
</tr>
<tr>
<td>$a_{4,c}$</td>
<td>$3d=36 \text{ mm}$</td>
<td>36 mm</td>
</tr>
</tbody>
</table>

* due to the application of draw bolts, minimum values of distances for both dowels and bolts should be considered (in case of differences between them)

**NOTE:** check if: $(n_r - 1)a_2 + 2a_{4,c} = h$
Characteristics of fasteners

Length of the dowel (lengths of the produced dowels change every 10 mm):

\[ L_d = \sum_{i} t_i + \left( 10 \div 15 \right) mm = 3 \cdot 50 + 2 \cdot 38 + 14 = 240 \text{ mm} \]

Length of the bolt shank:

\[ L_s = \sum_{i} t_i + 2g + m + \left( 5 \div 10 \right) mm = 226 + 2 \cdot 4 + 10,8 + 5,2 = 250 \text{ mm} \]

Length of the thread:

\[ L_g = L_s - \sum_{i} t_i - g = 250 - 226 - 4 = 20 \text{ mm} \]

Length of central and side members (2 mm clearance in the joint assumed):

\[ L = 2 \left[ (n - 1)a_1 + 2a_{3,t} \right] + 2 \text{ mm} = 2 \left[ (4 - 1) \cdot 120 + 2 \cdot 90 \right] + 2 = 1082 \text{ mm} \]
Nuts and washers

HEXAGON NUTS (PN-75/M-82144)

<table>
<thead>
<tr>
<th></th>
<th>M10</th>
<th>M12</th>
<th>M16</th>
<th>M20</th>
<th>M24</th>
</tr>
</thead>
<tbody>
<tr>
<td>d</td>
<td>10</td>
<td>12</td>
<td>16</td>
<td>20</td>
<td>24</td>
</tr>
<tr>
<td>$m_{max}$</td>
<td>8,4</td>
<td>10,8</td>
<td>14,8</td>
<td>18</td>
<td>21,5</td>
</tr>
<tr>
<td>$e_{min}$</td>
<td>17,77</td>
<td>20,03</td>
<td>26,75</td>
<td>32,95</td>
<td>39,55</td>
</tr>
<tr>
<td>$s_{max}$</td>
<td>16</td>
<td>18</td>
<td>24</td>
<td>30</td>
<td>36</td>
</tr>
</tbody>
</table>
Nuts and washers

SQUARE WASHERS
FOR TIMBER STRUCTURES (PN-75/M-82151)

<table>
<thead>
<tr>
<th>$d_o$</th>
<th>a</th>
<th>g</th>
<th>śruba</th>
</tr>
</thead>
<tbody>
<tr>
<td>12</td>
<td>30</td>
<td>3</td>
<td>M10</td>
</tr>
<tr>
<td>14</td>
<td>40</td>
<td>4</td>
<td>M12</td>
</tr>
<tr>
<td>16</td>
<td>50</td>
<td>5</td>
<td>M16</td>
</tr>
<tr>
<td>22</td>
<td>60</td>
<td>5</td>
<td>M20</td>
</tr>
<tr>
<td>26</td>
<td>80</td>
<td>6</td>
<td>M24</td>
</tr>
</tbody>
</table>
The correct scale drawing can be found in a separate PDF file.
In order to facilitate and accelerate the process of projects verification, please place the following data on the last page of the project:

- type of cross-section (with one or two chords)
- thickness of the chord [mm]
- thickness of the central member (if applies) [mm]
- thickness of the side member [mm]
- width of the connection [mm]
- $n_r$ - number of rows of fasteners [szt.]
- $n_1$ - number of fasteners in one row [szt.]
- $d$ - diameter of the fastener [mm]
- $g$ - thickness of the nut [mm]
- $m$ - thickness of the washer [mm]
- $f_{uk}$ - tensile strength of steel (EC3-1-8) [MPa]
- $L_d$ - length of the dowel [mm]
- $L_b$ - length of the bolt shank [mm]
- $L_g$ - length of the thread [mm]
- $L$ - length of central and side members (the whole connection) [mm]
- adopted fasteners spacings [mm]
The presented materials are the property of Division of Timber Structures.

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