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Characteristic vs. design values

The load parameters stated in the Technical Data Sheets are characteristic values. These values shall always be used in accordance with the partial factor method as described in Eurocode 5. With the partial factor method security is built into the construction as:

1. Security on the load parameters
2. Security on the material parameters

As nails belong to the second category, the design value of a nail is found by the following expression:

$$X_d = k_{mod} \frac{X_k}{\gamma_M}$$

d	Design (value, parameter, load)
k_{mod}	Is a modification factor taking the load duration and service class (moisture content) into consideration, e.g. k_{mod} for solid timber, service class 1, permanent action is 0,60
γ_M	Is the partial factor for a material property – e.g. γ_M for connections is 1,3
X	Can be expressed by e.g. a load carrying capacity (R) or a force (F)

Withdrawal and head pull-through

Smooth nails

The characteristic withdrawal capacity of nails - called $F_{ax,Rk}$ - can be calculated by using the formulas in Eurocode 5, chapter 8, Connections with metal fasteners.

The embedment length of the nail in the piece of wood where the nail point is located must be minimum 12 x the nail diameter to have the full withdrawal strength.

$F_{ax,Rk}$ = the smaller of the following values:

withdrawal: $f_{ax,k} \times d \times t_{pen}$

or

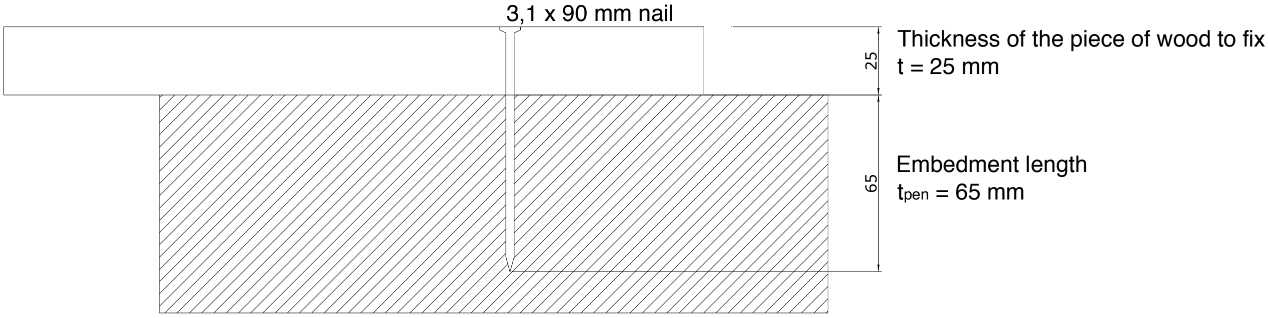
pull-through: $f_{ax,k} \times d \times t + f_{head,k} \times d_h^2$

$f_{ax,k}$	is the characteristic pointside withdrawal strength, $f_{ax,k} = 20 \times 10^{-6} \times \rho_k^2$
$f_{head,k}$	is the characteristic headside pull-through strength, $f_{head,k} = 70 \times 10^{-6} \times \rho_k^2$
d	is the nail diameter
t_{pen}	is the pointside penetration length in the piece of wood where the nail tip is located
t	is the thickness of the piece of wood where the nail head is located
d_h	is the head diameter (for D-head nails please use the values stated in Annex C)

Example, calculating a 3,1 x 90 mm smooth shank nail
Nail dimensions:

d = nominal nail diameter = 3,1 mm
d_h = head diameter = 6,80 mm
f_u = minimum wire tensile strength = 700 N/mm^2 (see actual value on Nail Data Sheet)
ρ_k = the characteristic wood density = 350 kg/m^3

Construction:



$f_{ax,k} =$ $20 \times 10^{-6} \times \rho_k^2 = 20 \times 10^{-6} \times 350^2 = 2{,}45$ N/mm^2
$f_{head,k} =$ $70 \times 10^{-6} \times \rho_k^2 = 70 \times 10^{-6} \times 350^2 = 8{,}58$ N/mm^2

$F_{ax,Rk} =$ $f_{ax,k} \times d \times t_{pen} = 2{,}45 \times 3{,}1 \times 65 = 493{,}7$ N for an embedment depth t_{pen} of 65 mm
or
$f_{ax,k} \times d \times t + f_{head,k} \times d_h^2 = 2{,}45 \times 3{,}1 \times 25 + 8{,}58 \times 6{,}8^2 = 586{,}6$ N

Result: The characteristic withdrawal strength is 493,7 N at a wood density of 350 kg/m^3.

Ring shank nails
For ring shank nails the characteristic strengths - called $f_{ax,k}$ (withdrawal) and $f_{head,k}$ (head pull-through) - must be determined by tests according to EN 1382 and EN 1383. The embedment length of the nail in the piece of wood where the nail point is located must be minimum 8 x the nail diameter to have the full withdrawal strength.

$F_{ax,Rk}$ = the smaller of the following values: withdrawal: $f_{ax,k} \times d \times t_{pen}$ or
pull-through: $f_{head,k} \times d_h^2$

$f_{ax,k}$	is the characteristic pointside withdrawal strength, determined by tests
$f_{head,k}$	is the characteristic headside pull-through strength, determined by tests
d	is the nail diameter
t_{pen}	is the pointside penetration length in the piece of wood where the nail point is located
d_h	is the head diameter

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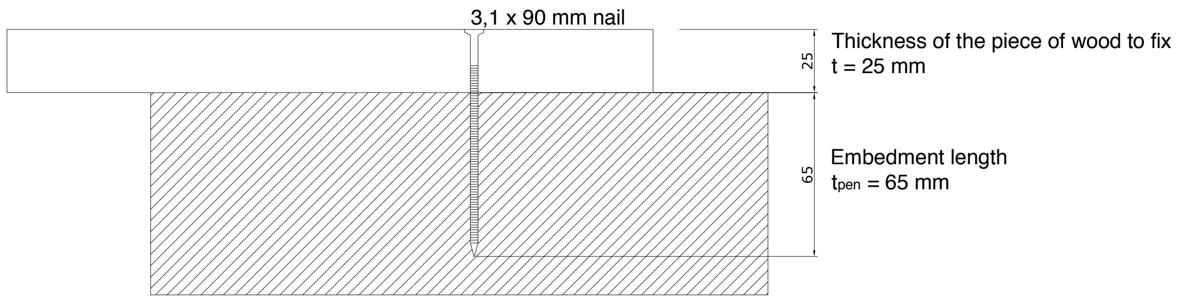
Example, calculating a 3,1 x 90 mm ring shank nail
Nail dimensions

d = nominal nail diameter = 3,1 mm
d_h = head diameter = 6,80 mm
ρ_k = the characteristic wood density = 350 kg/m^3

Construction:



$f_{ax,k}$ = 7,28 N/mm^2 (test result)
$f_{head,k}$ = 28,03 N/mm^2 (test result)

$F_{ax,Rk}$ = $f_{ax,k}$ x d x t_{pen} = 7,28 x 3,1 x 65 = 1466,9 N for an embedment depth t_{pen} of 65 mm
or
$f_{head,k}$ x d_h^2 = 28,03 x 6,8^2 = 1296,1 N

Result: The characteristic withdrawal strength is 1296, 1 N at a wood density of 350 kg/m^3.

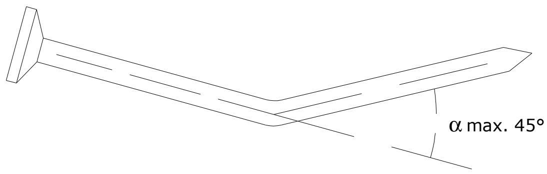
Yield moment

Smooth round nails
For smooth round nails produced from a wire with a minimum tensile strength of 600 N/mm^2 the characteristic yield moment i.e. the bending moment of the nail is calculated from the formula in Eurocode 5.

$M_{y,Rk} = 0,3 \times f_{u,k} \times d^{2,6}$

$M_{y,k}$ is the characteristic bending moment, in Nmm
$f_{u,k}$ is the tensile strength of the wire the nail is produced from, in N/mm^2
d is the nail diameter as defined in EN 14592 (the standard for timber structures and dowel-type fasteners), in mm

Maximum nail deformation according to EN 409



Example, calculating a 3,1 x 90 mm smooth shank nail
$f_{u,k}$ = minimum wire tensile strength 700 N/mm^2

$M_{y,Rk} = 0,3 \times f_{u,k} \times d^{2,6} = 0,3 \times 700 \times 3,1^{2,6} = 3979$ Nmm

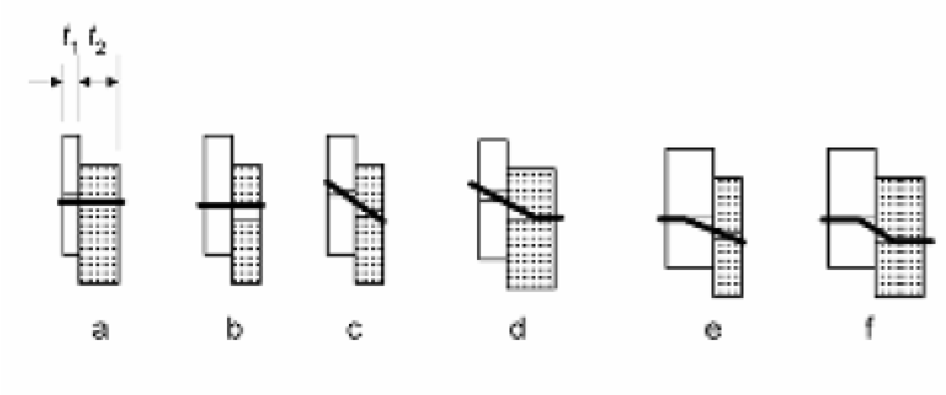
Ring shank nails
The yield moment of ring shank nails cannot be calculated, so tests according to EN 409:1993 (Timber structures – test methods – Determination of the yield moment of dowel-type fasteners) have to be carried out. The test gives you the characteristic yield moment directly in Nmm without any preceding calculations.

Shear - timber-to-timber and panel-to-timber connections

The characteristic load-carrying capacity for nails per shear plane per fastener is calculated from the following expressions from Eurocode 5.

For a single shear there are 6 different failure modes and the minimum value of the 6 expressions should be taken (the letters correspond to the drawings):

$$F_{v,Rk} = \min \begin{cases} f_{h,1,k} t_1 d & \text{(a)} \\ f_{h,2,k} t_2 d & \text{(b)} \\ \dfrac{f_{h,1,k} t_1 d}{1+\beta}\left[\sqrt{\beta + 2\beta^2\left[1+\dfrac{t_2}{t_1}+\left(\dfrac{t_2}{t_1}\right)^2\right]+\beta^3\left(\dfrac{t_2}{t_1}\right)^2}-\beta\left(1+\dfrac{t_2}{t_1}\right)\right]+\dfrac{F_{ax,Rk}}{4} & \text{(c)} \\ 1,05\dfrac{f_{h,1,k} t_1 d}{2+\beta}\left[\sqrt{2\beta(1+\beta)+\dfrac{4\beta(2+\beta)M_{y,Rk}}{f_{h,1,k}\, d\, t_1^2}}-\beta\right]+\dfrac{F_{ax,Rk}}{4} & \text{(d)} \\ 1,05\dfrac{f_{h,1,k} t_2 d}{1+2\beta}\left[\sqrt{2\beta^2(1+\beta)+\dfrac{4\beta(1+2\beta)M_{y,Rk}}{f_{h,1,k}\, d\, t_2^2}}-\beta\right]+\dfrac{F_{ax,Rk}}{4} & \text{(e)} \\ 1,15\sqrt{\dfrac{2\beta}{1+\beta}}\sqrt{2M_{y,Rk} f_{h,1,k} d}+\dfrac{F_{ax,Rk}}{4} & \text{(f)} \end{cases}$$



$F_{v,Rk}$	is the characteristic load-carrying capacity per shear per nail
t_1	is the thickness of the piece of timber to fasten
t_2	is the thickness of the second piece of timber, or the penetration depth of the nail – use the lower value of the two
$f_{h,1,k}$	is the characteristic embedment strength in timber piece 1
$f_{h,2,k}$	is the characteristic embedment strength in timber piece 2
d	nail diameter
$M_{y,Rk}$	the characteristic yield moment
ß	the radio between the embedment strength of the two timber pieces, see example below
$F_{ax,Rk}$	the characteristic withdrawal capacity of the nail (see the "Withdrawal and pull-through" paragraph)

The characteristic embedment strength is an expression which includes the pressure from the wood onto the nail and it is calculated from the formulas in Eurocode 5:

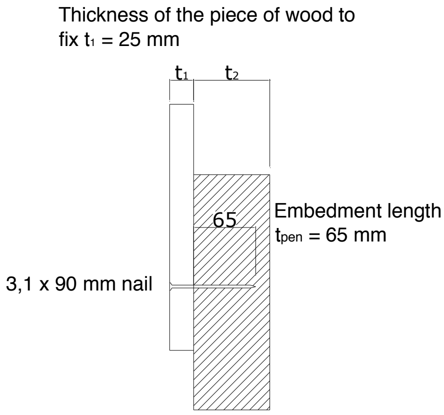
$f_{h,1,k} = 0{,}082 \times \rho_k \times d^{-0{,}3}$ N/mm^2 (for timber and LVL; for nails with a diameter < 8 mm; for other materials or dimensions, see Eurocode 5)

The ß-value is an expression which describes the ratio between the strength of the two different pieces of wood.

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

Example, calculating a 3,1 x 90 mm smooth shank nail
Nail dimensions:
d = nominal nail diameter = 3,1 mm
Timber used: Piece to fix, C24 => ρ_k = 350 kg/ m^3
Second piece, C30 => ρ_k = 380 kg/ m^3
$F_{ax,Rk}$ = 493,7 N (characteristic withdrawal capacity; taken from the above example)
$M_{y,Rk}$ = 3979 Nmm (characteristic yield moment; taken from the above example)
t_1 : 25 mm (timber to fix)
t_2 : 65 mm (if the embedment depth of the nail is less than the full thickness of the second piece of wood, t_2 is = the embedment depth).

Construction:



Formulas:

$$F_{\mathrm{v,Rk}} = \min \begin{cases} f_{\mathrm{h,1,k}} t_1 d & \text{(a)} \\ f_{\mathrm{h,2,k}} t_2 d & \text{(b)} \\ \dfrac{f_{\mathrm{h,1,k}} t_1 d}{1+\beta}\left[\sqrt{\beta + 2\beta^2\left[1+\dfrac{t_2}{t_1}+\left(\dfrac{t_2}{t_1}\right)^2\right]+\beta^3\left(\dfrac{t_2}{t_1}\right)^2} - \beta\left(1+\dfrac{t_2}{t_1}\right)\right] + \dfrac{F_{\mathrm{ax,Rk}}}{4} & \text{(c)} \\ 1{,}05\dfrac{f_{\mathrm{h,1,k}} t_1 d}{2+\beta}\left[\sqrt{2\beta(1+\beta)+\dfrac{4\beta(2+\beta)M_{\mathrm{y,Rk}}}{f_{\mathrm{h,1,k}}\, d\, t_1^2}} - \beta\right] + \dfrac{F_{\mathrm{ax,Rk}}}{4} & \text{(d)} \\ 1{,}05\dfrac{f_{\mathrm{h,1,k}} t_2 d}{1+2\beta}\left[\sqrt{2\beta^2(1+\beta)+\dfrac{4\beta(1+2\beta)M_{\mathrm{y,Rk}}}{f_{\mathrm{h,1,k}}\, d\, t_2^2}} - \beta\right] + \dfrac{F_{\mathrm{ax,Rk}}}{4} & \text{(e)} \\ 1{,}15\sqrt{\dfrac{2\beta}{1+\beta}}\sqrt{2M_{\mathrm{y,Rk}} f_{\mathrm{h,1,k}} d} + \dfrac{F_{\mathrm{ax,Rk}}}{4} & \text{(f)} \end{cases}$$

For a complete calculation example, see annex D.

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Annex - additional comments

A - Density correction
The density of all the test results has been reduced according to EN28970 and DIN 1052 (Verfahren 2), using the following formula to correct the density to a mean density of 350 kg/m^3:

$$k_\rho = \frac{\rho_k}{\rho}$$

Example: Characteristic withdrawal force = 1500 N; test wood density = 390 kg/m^3

The withdrawal force should be reduced with a factor of $\frac{350}{390}$ = 0,897

=> The characteristic withdrawal force is 1500 x 0,897 = 1346 N

B - Strength classes and timber densities
Strength classes – characteristic densities according to EN 338
(The number behind the "C" is the bending strength of the wood, $f_{m,k}$ in N/mm^2)

Strength class	C14	C16	C18	C20	C22	C24	C30	C35	C40
Characteristic density ρ_k [kg/m^3]	290	310	320	330	340	350	380	400	420
mean density ρ_{mean} [kg/m^3]	350	370	380	390	410	420	460	480	500

For further values and hardwood species, see EN 338.

Typical densities for construction wood, Northern Europe (source: Teknologisk Institut, Denmark):

Wood	Density min-max. [kg/m^3]
European spruce	370 - 440
douglas fir	440 - 530
larch	520 - 600
cedar (red)	380
pine	450 - 500

C - Head diameters
For a D-head nail the following table states the d_h-values to use for calculating $F_{ax,Rk}$. (The head diameter is equivalent to the diameter of a normal round head).

Nail shank diameter states the equivalent head diameter for a D-head nail								
shank diameter [mm]	2,2	2,5	2,8	3,1	3,4	3,8	4,0	4,2
head diameter [mm]	4,77	6,05	6,29	6,56	6,58	7,47	N/A	7,47

D - Example calculation
The characteristic embedment strength is calculated:

For timber piece 1, density ρ_k = 350 kg/m^3: $f_{h,1,k}$ = 0,082 x ρ_k x $d^{-0,3}$ = 0,082 x 350 x $3,1^{-0,3}$ = 20,44 N/mm^2
For timber piece 2, density ρ_k = 380 kg/m^3: $f_{h,2,k}$ = 0,082 x ρ_k x $d^{-0,3}$ = 0,082 x 380 x $3,1^{-0,3}$ = 22,19 N/mm^2

The expression ß is calculated:

$$\beta = \frac{f_{h,2,k}}{f_{h,1,k}} = \frac{0{,}082 \times \rho_k \times d^{-0,3}}{0{,}082 \times \rho_k \times d^{-0,3}} = \frac{22{,}19}{20{,}44} = 1{,}086$$

$$F_{v,Rk} = \min \begin{cases} f_{h,1,k}\, t_1\, d & \text{(a)} \\ f_{h,2,k}\, t_2\, d & \text{(b)} \\ \dfrac{f_{h,1,k}\, t_1\, d}{1+\beta}\left[\sqrt{\beta + 2\beta^2\left[1 + \dfrac{t_2}{t_1} + \left(\dfrac{t_2}{t_1}\right)^2\right] + \beta^3\left(\dfrac{t_2}{t_1}\right)^2} - \beta\left(1 + \dfrac{t_2}{t_1}\right)\right] + \dfrac{F_{ax,Rk}}{4} & \text{(c)} \\ 1{,}05\,\dfrac{f_{h,1,k}\, t_1\, d}{2+\beta}\left[\sqrt{2\beta(1+\beta) + \dfrac{4\beta(2+\beta)M_{y,Rk}}{f_{h,1,k}\, d\, t_1^2}} - \beta\right] + \dfrac{F_{ax,Rk}}{4} & \text{(d)} \\ 1{,}05\,\dfrac{f_{h,1,k}\, t_2\, d}{1+2\beta}\left[\sqrt{2\beta^2(1+\beta) + \dfrac{4\beta(1+2\beta)M_{y,Rk}}{f_{h,1,k}\, d\, t_2^2}} - \beta\right] + \dfrac{F_{ax,Rk}}{4} & \text{(e)} \\ 1{,}15\sqrt{\dfrac{2\beta}{1+\beta}}\sqrt{2M_{y,Rk}\, f_{h,1,k}\, d} + \dfrac{F_{ax,Rk}}{4} & \text{(f)} \end{cases}$$

(a) $f_{h,1,k}\, t_1\, d$ = 20,44 x 25 x 3,1 = 1584 N

(b) $f_{h,2,k}\, t_2\, d$ = 22,19 x 65 x 3,1 = 4471 N

(c) $$\frac{f_{h,1,k}\, t_1\, d}{1+\beta}\left[\sqrt{\beta + 2\beta^2\left[1 + \frac{t_2}{t_1} + \left(\frac{t_2}{t_1}\right)^2\right] + \beta^3\left(\frac{t_2}{t_1}\right)^2} - \beta\left(1 + \frac{t_2}{t_1}\right)\right] + \frac{F_{ax,Rk}}{4}$$

$$\frac{20{,}44 \times 25 \times 3{,}1}{1 + 1{,}086}\left[\sqrt{1{,}086 + 2 \times 1{,}086^2\left[1 + \frac{65}{25} + \left(\frac{65}{25}\right)^2\right] + 1{,}086^3\left(\frac{65}{25}\right)^2} - 1{,}086\left(1 + \frac{65}{25}\right)\right] + \frac{493{,}7}{4}$$

2087,62 + 123,43 = 2211 N

Check if 15% of 2087,62 > $\frac{F_{ax,Rk}}{4}$ = 2087,62 x 0,15 > 123,43 = 313,14 > 123,43 OK

(d)

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

$$1{,}05\,\frac{20{,}44\ x\ 25\ x\ 3{,}1}{2+1{,}086}\left[\sqrt{2\ x\ 1{,}086(1+1{,}086)+\frac{4\ x\ 1{,}086(2+1{,}086)3979}{20{,}44\ x\ 3{,}1\ x\ 25^2}}-1{,}086\right]+\frac{493{,}7}{4}$$

721,40 + 123,43

Check if 15% of 721,40 > $\frac{F_{ax,Rk}}{4}$ = 721,40 x 0,15 > 123,43 = 108,21 > 123,43 NO! Therefore: 108,21 OK!
721,40 + 108,21 = 830 N

(e)

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

$$1{,}05\,\frac{20{,}44\ x\ 65\ x\ 3{,}1}{1+2\ x\ 1{,}086}\left[\sqrt{2\ x\ 1{,}086^2(1+1{,}086)+\frac{4\ x\ 1{,}086(1+2\ x\ 1{,}086)3979}{20{,}44\ x\ 3{,}1\ x\ 65^2}}-1{,}086\right]+\frac{493{,}7}{4}$$

1605,77 + 123,43 = 1729 N

Check if 15% of 1605,77 > $\frac{F_{ax,Rk}}{4}$ = 1605,77 x 0,15 > 123,43 = 240,87 > 123,43 OK

(f)

$$1.15\sqrt{\frac{2\beta}{1+\beta}}\sqrt{2M_{y,Rk}\,f_{h,1,k}\,d}+\frac{F_{ax,Rk}}{4}$$

$$1{,}15\sqrt{\frac{2\ x\ 1{,}086}{1+1{,}086}}\sqrt{2\ x\ 3979\ x\ 20{,}44\ x\ 3{,}1}+\frac{493{,}7}{4}$$

832,95 + 123,43 = 956 N

Check if 15% of 832,95> $\frac{F_{ax,Rk}}{4}$ = 832,95 x 0,15 > 123,43 = 124,94 > 123,43 OK

Summary:

$$F_{v,Rk}=min\begin{cases}\text{(a) 1584 N}\\\text{(b) 4471 N}\\\text{(c) 2211 N}\\\text{(d) 830 N}\\\text{(e) 1729 N}\\\text{(f) 956 N}\end{cases}$$

As $F_{v,Rk}$ is defined as the lowest value of the 6 expressions above, the load bearing capacity per nail per shear for this construction is 830 N.

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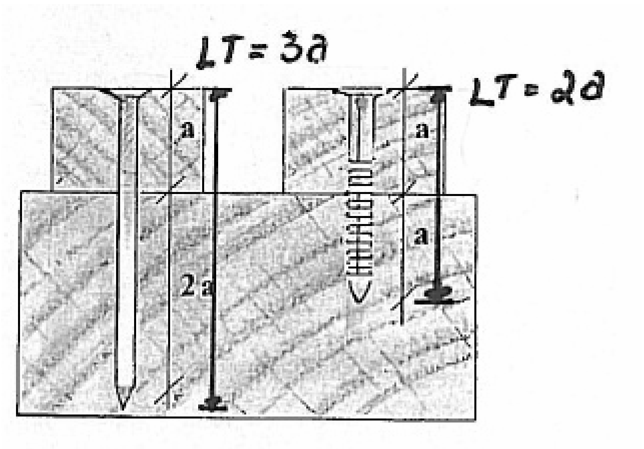
E – Nail length selection
According to Traeinformation (a Danish NGO representing 1300+ companies related to the wood and/or construction business) the right length of a nail shall be defined following below rules stated below:

Smooth Nail
The total length (LT) of the nail should be 3x as long as the piece of wood to fix (rule of thumb, therefore always compare with your own national rules). Please refer to the following drawing.

Ring Nail
The total length (LT) of the nail should be 2x as long as the piece of wood to fix (rule of thumb, therefore always compare with your own national rules). Please refer to the following drawing.



Please note that Paslode & Duo-Fast products are dedicated to trained & qualified professional end users.

Nails must be selected according to the nature of base materials, the load to be supported and exterior conditions. The choice of nails has to be checked and approved according to technical data, precise calculations and on-site tests if needed. Instructions for use must be strictly followed.

Paslode Duo-Fast reserves the right to modify characteristics of their products at any time. Pictures used cannot be considered as representative.