LIGNOLOC®
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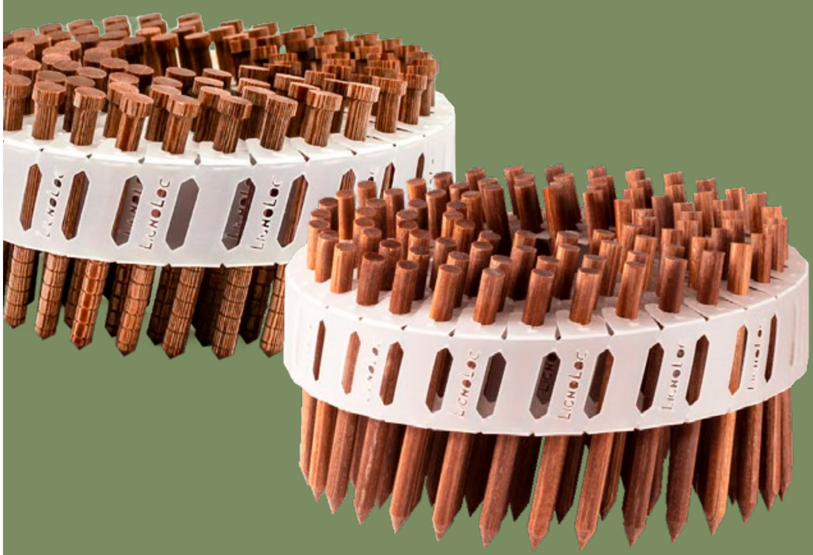
STRUCTURAL ANALYSIS

Fastening of a Clapboard

with LIGNOLOC® wooden nails



Calculation performed by:
BIGA | Structural Engineers
Prof. Dr. Ing. Patrik Aondio
An der Halde 3 | 87448 Waltenhofen | Germany
Phone: +49 (0) 8379 / 880 900-3
Email: aondio@biga-bauingenieure.de
Website: biga-bauingenieure.de

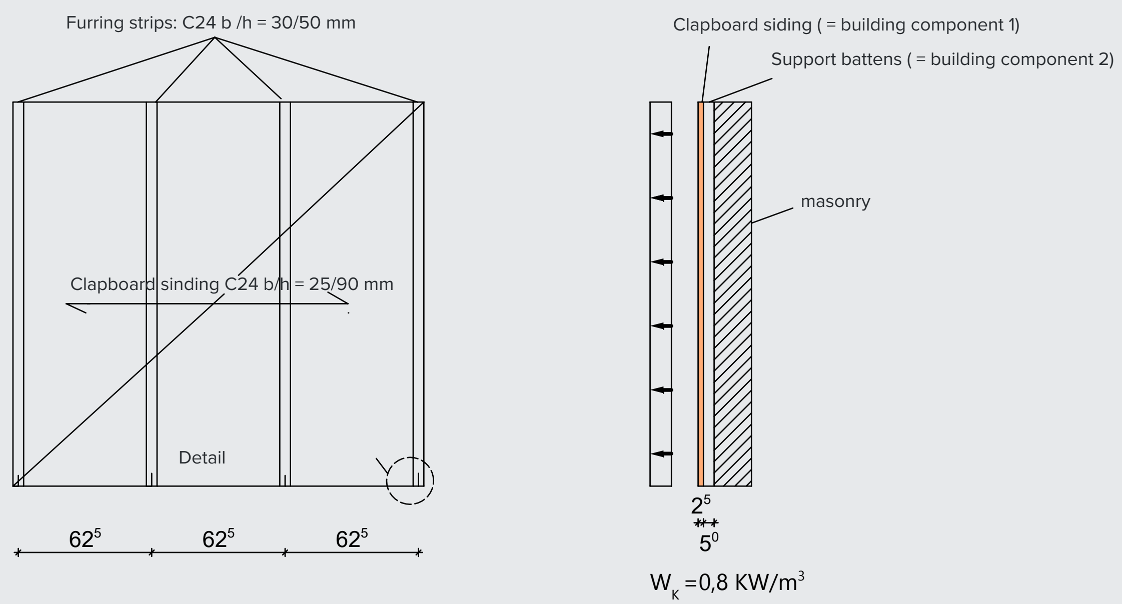
01 // System

A clapboard siding installed on a structural framework made of spruce timber is considered. Based on the local conditions, the façade can be assigned to Service Class 2.

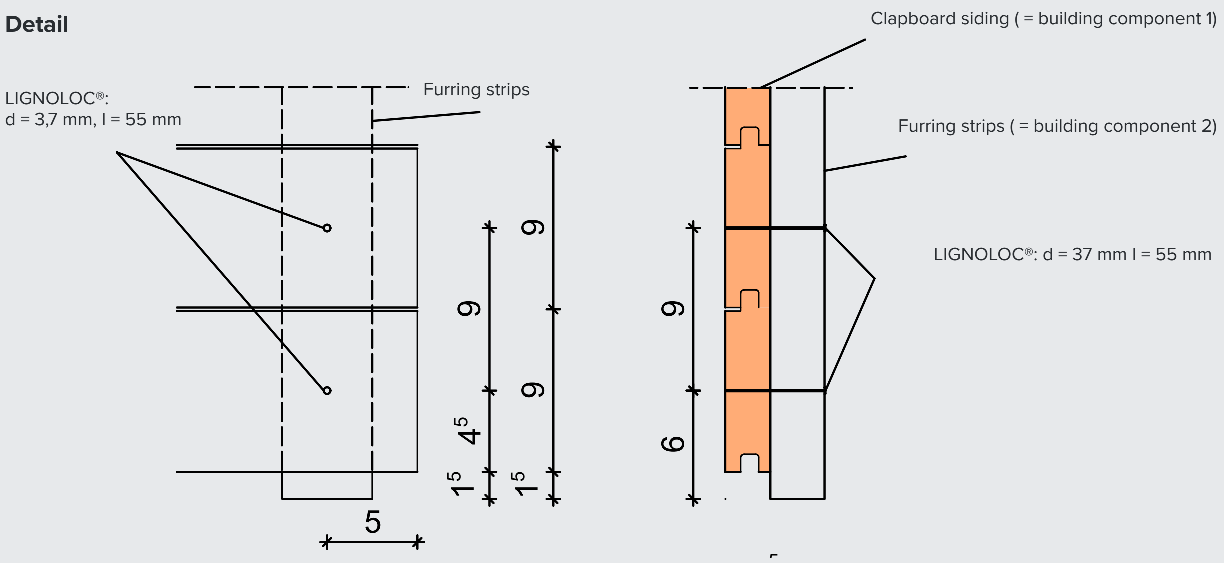
Support battens: Softwood C24, $b_{Ri} \times h_{Ri}$ = 30 x 50 mm², e= 625mm, NKL 2

Clapboard sinding: Softwood C24, $b_S \times h_S$ = 25 x 90 mm², NKL 2

Connection: LIGNOLOC® wooden nail, d=3,7mm, l=55 mm, a_1 = 90 mm



Detail



An analysis of the entire building resulted in a governing characteristic wind uplift load of 0.8 kN/m². For the clapboard siding, an average unit weight of $\rho_{\text{mean, Timber}} = 4{,}2\ \text{kN}/\text{m}^2$ can be assumed.

02 // Verification of the Minimum Spacings

Fasteners according to ETA-23/0041, analogous to non-pre-drilled nails in DIN EN 1995-1-1:2010-12

Are the minimum spacings in the clapboard siding (Component 1) met?

table 8.2

$$\mathrm{a}_{1,\mathrm{min,VH}} = (5 + 5 \cdot (\cos\alpha)) \cdot \mathrm{d} = (5 + 5 \cdot (\cos 90^\circ)) \cdot 3{,}7 = 18{,}5\ \mathrm{mm} \leq 625\ \mathrm{mm}\ ✓$$

$$\mathrm{a}_{3,\mathrm{c,min,VH}} = 10 \cdot \mathrm{d} = 10 \cdot 3{,}7 = 37{,}0\ \mathrm{mm} \leq 50\ \mathrm{mm}\ ✓$$

$$a_{4,t,\mathrm{min,VH}} = (5 + 2 \cdot \sin\alpha) \cdot d = (5 + 2 \cdot (\sin 90^\circ)) \cdot 3{,}7 = 25{,}9\ \mathrm{mm} \leq 45\ \mathrm{mm}\ ✓$$

$$a_{4,c,\mathrm{min,VH}} = 5 \cdot d = 5 \cdot 3{,}7 = 18{,}5\ \mathrm{mm} \leq 45\ \mathrm{mm}\ ✓$$

Are the minimum spacings in the furring strips (Component 2) met?

table 8.2

$$a_{1,\mathrm{min,VH}} = (5 + 5 \cdot (\cos\alpha)) \cdot d = (5 + 5 \cdot (\cos 0^\circ)) \cdot 3{,}7 = 37\ \mathrm{mm} \leq 90\ \mathrm{mm}\ ✓$$

$$\mathrm{a}_{3,\mathrm{t,min,VH}} = (10 + 5 \cdot (\cos\alpha\ )) \cdot \mathrm{d} = (10 + 5 \cdot (\cos 0^\circ)) \cdot 3{,}7 = 55\ \mathrm{mm} \leq 60\ \mathrm{mm}\ ✓$$

$$a_{4,c,\mathrm{min,VH}} = 5 \cdot d = 5 \cdot 3{,}7 = 18{,}5\ \mathrm{mm} \leq 25\ \mathrm{mm}\ ✓$$

03 // Loads per Nail

From permanent load

$$\mathrm{F}_{\mathrm{V,G,k}} = \rho_{\mathrm{mean,Timber}} \cdot \mathrm{b}_{\mathrm{S}} \cdot \mathrm{h}_{\mathrm{S}} \cdot \mathrm{e} = 4{,}2 \frac{\mathrm{kN}}{\mathrm{m}^3} \cdot 0{,}025\mathrm{m} \cdot 0{,}090\mathrm{m} \cdot 0{,}625\mathrm{m} = 5{,}9 \cdot 10^{-3}\mathrm{kN} = 5{,}9\ \mathrm{N}$$

Design level

$$F_{V,G,d} = F_{V,G,k} \cdot \gamma_G = 5{,}9\ N \cdot 1{,}35 = 8{,}0\ N$$

Wind load

$$\mathrm{F}_{\mathrm{ax,W,k}} = \underbrace{1{,}25}_{\text{continuity factor}} \cdot \mathrm{w}_{\mathrm{k}} \cdot \mathrm{h}_{\mathrm{S}} \cdot \mathrm{e} = 1{,}25 \cdot 0{,}8 \frac{\mathrm{kN}}{\mathrm{m}^2} \cdot 0{,}090\ \mathrm{m} \cdot 0{,}625\ \mathrm{m} = 0{,}056\ \mathrm{kN} = 56{,}2\ \mathrm{N}$$

At the design level

$$F_{ax,W,d} = F_{ax,W,k} \cdot \gamma_Q = 56{,}2\ N \cdot 1{,}5 = 84{,}3\ N$$

04 // Verification of Permanent Load

Embedding strength of solid timber – nail head side (α_1=90°)

according to ETA

$$f_{h,1,k} = \frac{0{,}082 \cdot \rho_{k,1} \cdot d^{-0{,}3}}{(1{,}35 + 0{,}015 \cdot d) \cdot \sin^2\alpha_1 + \cos^2\alpha_1}$$

$$f_{h,1,k} = \frac{0{,}082 \cdot 350\,kg/m^3 \cdot 3{,}7^{-0{,}3}}{(1{,}35 + 0{,}015 \cdot 3{,}7) \cdot (\sin 90^\circ)^2 + (\cos 90^\circ)^2} = 13{,}79\,N/\mathrm{mm}^2$$

nach DIN EN 1995-1-1, Tab. 3.1

$$k_{mod,1} = 0{,}6$$

$$f_{h,1,d} = \frac{f_{h,1,k} \cdot k_{mod,1}}{\gamma_{M,1}} = \frac{13{,}79 \cdot 0{,}6}{1{,}3} = 6{,}37\,N/mm^2$$

Embedding strength of solid timber – nail tip side (α_2 = 0°)

according to ETA

$$f_{h,2,k} = \frac{0{,}082 \cdot \rho_{k,2} \cdot d^{-0{,}3}}{(1{,}35 + 0{,}015 \cdot d) \cdot \sin^2\alpha_2 + \cos^2\alpha_2} =$$

$$f_{h,2,k} = \frac{0{,}082 \cdot 350\,kg/m^3 \cdot 3{,}7^{-0{,}3}}{(1{,}35 + 0{,}015 \cdot 3{,}7) \cdot (\sin 0^\circ)^2 + (\cos 0^\circ)^2} = 19{,}38\,N/mm^2$$

according to DIN EN 1995-1-1, Tab. 3.1

$$k_{mod,2} = 0{,}6$$

$$f_{h,2,d} = \frac{f_{h,2,k} \cdot k_{mod,2}}{\gamma_{M,2}} = \frac{19{,}38 \cdot 0{,}6}{1{,}3} = 8{,}95\,N/mm^2$$

$$\beta = \frac{f_{h,2,d}}{f_{h,1,d}} = \frac{8{,}95\,N/mm^2}{6{,}37\,N/mm^2} = 1{,}41$$

Design value of the yield moment

ETA-table B.1

$$M_{u,k} = 1200\,Nmm$$

$$M_{u,d} = M_{u,k} \cdot \frac{k_{mod,M}}{\gamma_M} = 1200\,Nmm \cdot \frac{0{,}35}{1{,}3} = 323\,Nmm$$

Required minimum embedment depth 1 – nail head side

according to ETA

$$t_{1,req} = \left(\sqrt{\frac{\beta}{1+\beta}} + 1\right) \cdot \sqrt{\frac{4 \cdot M_{u,d}}{0{,}75 \cdot f_{h,1,d} \cdot d}} = \left(\sqrt{\frac{1{,}41}{1+1{,}41}} + 1\right) \cdot \sqrt{\frac{4 \cdot 323\,Nmm}{0{,}75 \cdot 6{,}37 \cdot \frac{N}{mm^2} \cdot 3{,}7}} = 15{,}09\,mm$$

$$t_{1,req} = 15{,}09\,mm \leq t_{1,vorh} = 25{,}0\,mm \checkmark$$

Required minimum embedment depth 2 – nail tip side

according to ETA

$$t_{2,req} = \left(\sqrt{\frac{1}{1+\beta}} + 1\right) \cdot \sqrt{\frac{4 \cdot M_{u,d}}{0{,}75 \cdot f_{h,2\,d} \cdot d}} = \left(\sqrt{\frac{1}{1+1{,}41}} + 1\right) \cdot \sqrt{\frac{4 \cdot 323\,Nmm}{0{,}75 \cdot 8{,}95 \frac{N}{mm^2} \cdot 3{,}7}} = 11{,}87\,mm$$

$$t_{2,req} = 11{,}87\,mm \leq t_{2,vorh} = 30{,}0\,mm \checkmark$$

Design of the load-bearing capacity in shear per nail

$$F_{v,Rd,Na} = \sqrt{\frac{2 \cdot \beta}{1+\beta}} \cdot \sqrt{1{,}5 \cdot M_{u,d} \cdot f_{h,1,d} \cdot d}$$

$$F_{v,Rd,Na} = \sqrt{\frac{2 \cdot 1{,}41}{1+1{,}41}} \cdot \sqrt{1{,}5 \cdot 323\,Nmm \cdot 6{,}37\,N/mm^2 \cdot 3{,}7\,mm}$$

$$F_{v,Rd,Na} = 115{,}59\,N$$

Verification

$$\eta = \frac{F_{V,G,d}}{F_{v,Rd,Na}} = \frac{8{,}0\,N}{115{,}59\,N} = 0{,}06 < 1{,}0 \left(\text{utilization ratio } 6\%\right)$$

05 // Verification of permanent and temporary loads

Embedding strength of solid timber – nail head side (α_1 = 90°)

according to ETA

$$f_{h,1,k} = \frac{0{,}082 \cdot \rho_{k,1} \cdot d^{-0{,}3}}{(1{,}35 + 0{,}015 \cdot d) \cdot \sin^2\alpha_1 + \cos^2\alpha_1}$$

$$f_{h,1,k} = \frac{0{,}082 \cdot 350\,kg/m^3 \cdot 3{,}7^{-0{,}3}}{(1{,}35 + 0{,}015 \cdot 3{,}7) \cdot (\sin 90^\circ)^2 + (\cos 90^\circ)^2} = 13{,}79\,N/mm^2$$

$k_{mod,1} = 1{,}0$ Load duration class: medium, between short-term and very short-term

according to DIN EN 1995-1-1, Tab. 3.1

$$f_{h,1,d} = \frac{f_{h,1,k} \cdot k_{mod,1}}{\gamma_{M,1}} = \frac{13{,}79 \cdot 1{,}0}{1{,}3} = 10{,}61\,N/mm^2$$

Required minimum embedment deph 2 – Side of the nail tip (α_2=0°)

according to ETA

$$f_{h,2,k} = \frac{0{,}082 \cdot \rho_{k,2} \cdot d^{-0{,}3}}{(1{,}35 + 0{,}015 \cdot d) \cdot \sin^2\alpha_2 + \cos^2\alpha_2} =$$

$$f_{h,2,k} = \frac{0{,}082 \cdot 350\,kg/m^3 \cdot 3{,}7^{-0{,}3}}{(1{,}35 + 0{,}015 \cdot 3{,}7) \cdot (\sin 0^\circ)^2 + (\cos 0^\circ)^2} = 19{,}38\,N/mm^2$$

$k_{mod,2} = 1{,}0$ (Load duration class: medium, between short-term and very short-term)

according to DIN EN 1995-1-1, Tab. 3.1

$$f_{h,2,d} = \frac{f_{h,2,k} \cdot k_{mod,2}}{\gamma_{M,2}} = \frac{19{,}38 \cdot 1{,}0}{1{,}3} = 14{,}91\ N/mm^2$$

$$\beta = \frac{f_{h,2,d}}{f_{h,1,d}} = \frac{14{,}91\ N/mm^2}{10{,}61\ N/mm^2} = 1{,}41$$

Design value of the yield moment

ETA-table B.1

$$M_{u,k} = 1200\ \text{Nmm}$$

To remain on the safe side, the load duration class “short-term” is assumed for the wind action.

$$M_{u,d} = M_{u,k} \cdot \frac{k_{mod,M}}{\gamma_M} = 1200\ \text{Nmm} \cdot \frac{0{,}60}{1{,}3} = 554\ \text{Nmm}$$

Required minimum embedment depth 1 – nail head side

according to ETA

$$t_{1,req} = \left(\sqrt{\frac{\beta}{1+\beta}} + 1\right) \cdot \sqrt{\frac{4 \cdot M_{u,d}}{0{,}75 \cdot f_{h,1,d} \cdot d}} = \left(\sqrt{\frac{1{,}41}{1+1{,}41}} + 1\right) \cdot \sqrt{\frac{4 \cdot 554\ \text{Nmm}}{0{,}75 \cdot 10{,}61 \cdot \frac{N}{mm^2} \cdot 3{,}7}} = 15{,}31\ mm$$

$$t_{1,req} = 15{,}31\ mm \le\ t_{1,vorh} = 25{,}0\ mm ✓$$

Required minimum embedment depth 2 – nail tip side

according to ETA

$$t_{2,req} = \left(\sqrt{\frac{1}{1+\beta}}\ +\ 1\right) \cdot \sqrt{\frac{4 \cdot M_{u,d}}{0{,}75 \cdot f_{h,2,d} \cdot d}} = \left(\sqrt{\frac{1}{1+1{,}41}} + 1\right) \cdot \sqrt{\frac{4 \cdot 554\ \text{Nmm}}{0{,}75 \cdot 14{,}91 \frac{N}{mm^2} \cdot 3{,}7}} = 12{,}04\ mm$$

$$t_{2,req} = 12{,}04\ mm \le\ t_{2,vorh} = 30{,}0\ mm ✓$$

Design of the load-bearing capacity in shear per nail

$$F_{v,Rd,Na} = \sqrt{\frac{2 \cdot \beta}{1+\beta}} \cdot \sqrt{1{,}5 \cdot M_{u,d} \cdot f_{h,1,d} \cdot d}$$

$$F_{v,Rd,Na} = \sqrt{\frac{2 \cdot 1{,}41}{1+1{,}41}} \cdot \sqrt{1{,}5 \cdot 554\ \text{Nmm} \cdot 10{,}61\ N/mm^2\ \cdot\ 3{,}7\ mm}$$

$$F_{v,Rd,Na} = 195{,}21\ N$$

Determination of the withdrawal capacity

Verification of the minimum penetration depth in component 1 – nail head side:

$$t_{pen,min,1} = 4 \cdot d = 4 \cdot 3{,}7\ mm = 14{,}8\ mm$$

$$t_{pen,min,1} = 14{,}8\ mm \leq\ t_{pen,vorh,1} = 25{,}0\ mm\ \checkmark$$

Verification of the minimum penetration depth in component 2 – nail tip side:

$$t_{\mathrm{pen,min,2}} = 8 \cdot d = 8 \cdot 3{,}7\ mm = 29{,}6\ mm$$

$$t_{\mathrm{pen,min,2}} = 29{,}6\ \mathrm{mm} \leq t_{\mathrm{pen,vorh,2}} = 30{,}0\ \ \mathrm{mm}\ \checkmark$$

Withdrawal capacity on the nail head side – component 1

$$\mathrm{F_{ax,Rd,1}} = \mathrm{min}\begin{Bmatrix} 1 \\ \frac{\mathrm{t_{pen,1}}}{8 \cdot \mathrm{d}} \end{Bmatrix} \cdot \frac{\mathrm{f_{ax,k}} \cdot \mathrm{k_{mod,ax}}}{\gamma_{\mathrm{M,1}}} \cdot \mathrm{d} \cdot \mathrm{t_{pen,1}} \cdot \left(\frac{\rho_{\mathrm{k,1}}}{350}\right)^{0,8} =$$

$$\mathrm{F_{ax,Rd,1}} = \mathrm{min}\begin{Bmatrix} 1 \\ \frac{25}{8 \cdot 3,7} \end{Bmatrix} \cdot \frac{7{,}0\ \frac{\mathrm{N}}{\mathrm{mm}^2} \cdot 0{,}5}{1{,}3} \cdot 3{,}7 \cdot 25\ \mathrm{mm} \cdot \left(\frac{350}{350}\right)^{0,8} =$$

$$\mathrm{F_{ax,Rd,1}} = 0{,}84 \cdot \frac{7{,}0\ \frac{\mathrm{N}}{\mathrm{mm}^2} \cdot 0{,}5}{1{,}3} \cdot 3{,}7 \cdot 25\ \mathrm{mm} \cdot 1{,}0 = 210\ \mathrm{N}$$

Withdrawal capacity on the nail tip side – component 2

$$\mathrm{F_{ax,Rd,2}} = \mathrm{min}\begin{Bmatrix} 1 \\ \frac{\mathrm{t_{pen,2}}}{8 \cdot \mathrm{d}} \end{Bmatrix} \cdot \frac{\mathrm{f_{ax,k}} \cdot \mathrm{k_{mod,ax}}}{\gamma_{\mathrm{M,2}}} \cdot \mathrm{d} \cdot \mathrm{t_{pen,2}} \cdot \left(\frac{\rho_{\mathrm{k,2}}}{350}\right)^{0,8} =$$

$$\mathrm{F_{ax,Rd,2}} = \mathrm{min}\begin{Bmatrix} 1 \\ \frac{30}{8 \cdot 3,7} \end{Bmatrix} \cdot \frac{7{,}0\ \frac{\mathrm{N}}{\mathrm{mm}^2} \cdot 0{,}5}{1{,}3} \cdot 3{,}7 \cdot 30\ \mathrm{mm} \cdot \left(\frac{350}{350}\right)^{0,8} =$$

$$\mathrm{F_{ax,Rd,2}} = 1{,}0 \cdot \frac{7{,}0\ \frac{\mathrm{N}}{\mathrm{mm}^2} \cdot 0{,}5}{1{,}3} \cdot 3{,}7 \cdot 30\ \mathrm{mm} \cdot 1{,}0 = 299\ \mathrm{N}$$

Withdrawal resistance:

$$F_{ax,Rd} = min\begin{Bmatrix} F_{ax,Rd,1} \\ F_{ax,Rd,2} \end{Bmatrix} = min\begin{Bmatrix} 210\ N \\ 299\ N \end{Bmatrix} = 210\ N$$

Verification (combined verification)

$$\eta = \frac{\mathrm{F_{V,G,d}}}{\mathrm{F_{v,Rd,Na}}} + \frac{\mathrm{F_{ax,W,d}}}{\mathrm{F_{ax,Rd}}} = \frac{8{,}0\ \mathrm{N}}{195{,}21\ \mathrm{N}} + \frac{84{,}3\ \mathrm{N}}{210\ \mathrm{N}} = 0{,}44 < 1{,}0\ \left(\text{utilization ratio } 44\%\right)$$

BECK

BECK Fastening
Raimund-Beck-Strasse 1
5270 Mauerkirchen | Austria
T +43 7724 2111-0
sales.int@beck-fastening.com
BECK-FASTENING.COM

Version 11/25 EN