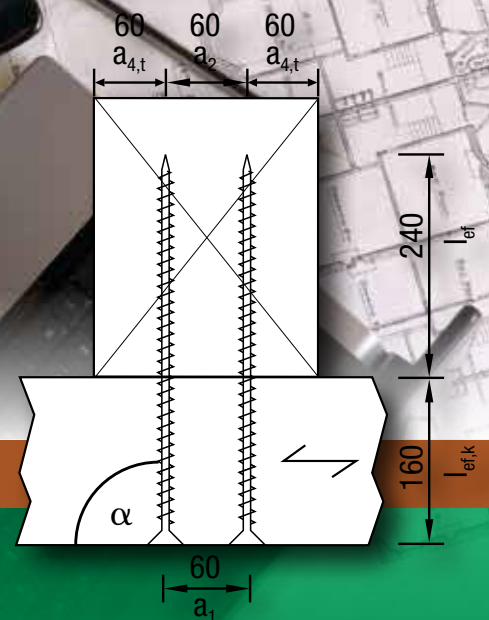


Construction

Design guidelines

Guidelines for the design of structural connections with SPAX fasteners



You can also use the
SPAX design software at:
<https://designsoftware.spax.com>

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1. Introduction

This guide the design and installation of loadbearing connections with SPAX fasteners in accordance with BS EN 1995-1-1:2004+A2:2014 (Eurocode 5 resp. EC5) and its National Annex dated October 2012, and in accordance with European Technical Approval ETA-12/0114.

It is aimed at quick predesign of loadbearing connections with SPAX fasteners, but is not intended to replace appropriate engineering and design by a design professional.

In absence of further specific provisions in the European Technical Approval (ETA), EC5 and its National Annexes apply to the design and installation of connections. Outside the European Union, national standards shall be considered as well.

This document solely covers requirements relative to load-carrying capacity and serviceability of connections.

In addition to EC5 provisions, specific design prescriptions are provided in the relevant sections, and shall be considered as minimum requirements. They may need to be extended to particular connection configurations.

Members of solid timber, glued-laminated timber, laminated veneer lumber (LVL), wood-based products (in accordance with their ETA or national approval) or steel may be connected to further members of solid timber, glued-laminated timber, laminated veneer lumber (LVL), wood-based products (in accordance with their ETA or national approval).

Connections to wood-based panels (particle board, fibre board, OSB or plywood) may be designed in accordance with the prescriptions of the ETA or national approval of the relevant panel, provided screwed connection is accepted or covered in its scope.

This guide has been established in good faith and to the best of our knowledge. No liability is therefore engaged or accepted for any obvious mistake or error.

Please send any suggestion, question or proposal for corrections to technik@spax.com.



You can also use the SPAX design software to calculate your projects in accordance with EC5 + ETA. The new browser-based version offers online calculation with the modules General Screw Calculation (shearing + withdrawal), Notch Reinforcement, Transverse Pressure Reinforcement, Above-Rafter Insulation and Main and Secondary Beam Connection with server-based storage option (file hosting) and project management. For a more detailed description of the programme, please see the SPAX Design Software Quick Guide at: downloads.spax.com

To directly access the software, go to: <https://designsoftware.spax.com>

If you use the programme frequently, we recommend placing a bookmark.

ETA-12/0114

2. Definitions and nomenclature

Symbols used in the equations

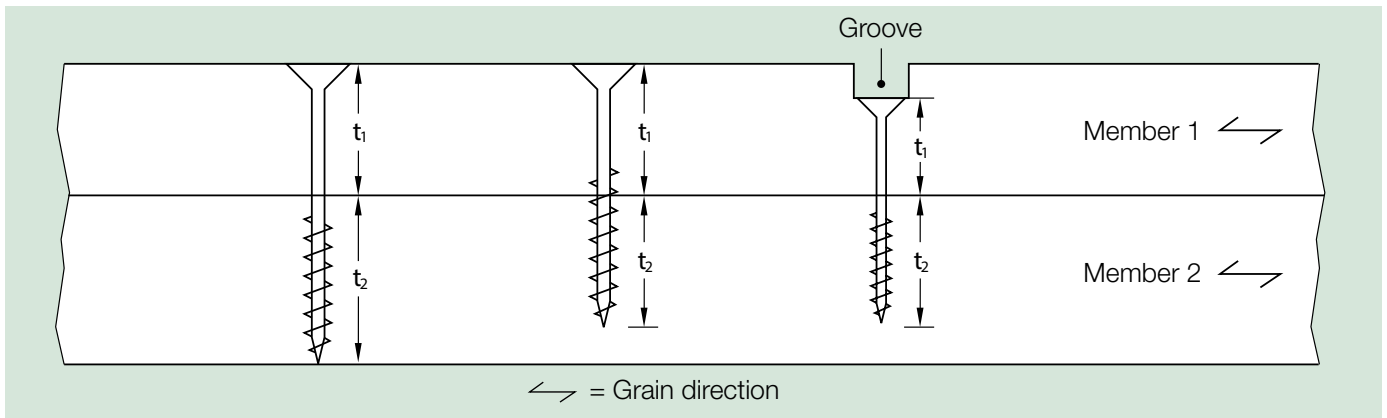
$F_{v,Ed}$	Design value of the shear force acting on the fastener	[N]	
$F_{v,Ek}$	Characteristic value of the shear force acting on the fastener	[N]	
$F_{ax,\alpha,Ed}$	Design value of the axial force acting on the fastener	[N]	
$F_{ax,\alpha,Ek}$	Characteristic value of the axial force acting on the fastener	[N]	
$M_{y,k}$	Characteristic value of the fastener yield moment	[Nm]	ETA
$F_{v,Rd}$	Design value of fastener shear resistance, per fastener and per shear plane	[N]	
$F_{v,Rk}$	Characteristic value of fastener shear resistance, per fastener and per shear plane	[N]	EC5 ; §8.2.2 (1)
ΔR_k	Characteristic value of additional fastener shear resistance due to rope effect	[N]	EC5 ; §8.2.2 (2)
$F_{ax,\alpha,Rd}$	Design value of fastener axial withdrawal resistance	[N]	
$F_{ax,\alpha,Rk}$	Characteristic value of fastener axial withdrawal resistance	[N]	ETA
$f_{tens,d}$	Design value of steel tensile resistance	[N]	
$f_{tens,k}$	Characteristic value of steel tensile resistance	[N]	ETA
d_1	Outer thread diameter	[mm]	ETA annexes
d_h	Head diameter	[mm]	ETA annexes
$f_{ax,k}$	Characteristic withdrawal parameter	[N/mm ²]	ETA
$f_{head,k}$	Characteristic head pull-through parameter	[N/mm ²]	ETA
$f_{h,k}$	Characteristic embedment strength of timber	[N/mm ²]	ETA
k_{mod}	Modification factor for duration of load and moisture content		
l_{ef}	Effective threaded length in member 2 (pointside)	[mm]	
$l_{ef,k}$	Effective threaded length in member 1 (headside)	[mm]	
l_g	Threaded length of screw	[mm]	ETA annexes
n_{ef}	Effective number of fasteners	[]	EC5 ; §8.7, ETA
t	Thickness (e.g. of a member)	[mm]	
t_1	Thickness or penetration depth in member 1 (headside)	[mm]	
t_2	Thickness or penetration depth in member 2 (pointside)	[mm]	
t_{req}	Required thickness or penetration depth	[mm]	
u_{gl}	Wood equilibrium moisture content	[%]	
α	Angle between the screw axis and the direction of the grain	[°]	ETA
α'	Angle between the direction of the resultant force and the direction of the grain	[°]	
β	Ratio of embedment strengths $f_{h,2,k}/f_{h,1,k}$	[]	EC5 ; §8.2.2
γ_M	Partial factor for material properties (under static or quasi-static loading)		
ρ_k	Characteristic density of the wood or wood based member	[kg/m ³]	



2. Definitions and nomenclature

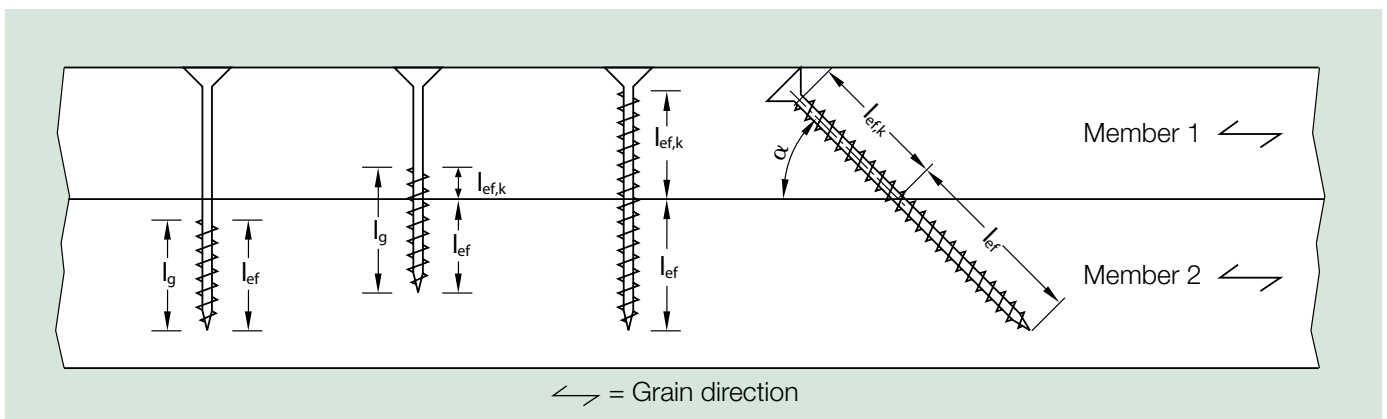
Design with loading perpendicular to the screw axis – Shear

Figure 2.1 Determination of thicknesses resp. penetration depths t_1 and t_2



Design with loading parallel to the screw axis – Withdrawal

Figure 2.2 Determination of effective threaded lengths l_{ef} and $l_{ef,k}$



3. Design value of the resistance

3.1 Design value of the shear resistance

Design value of the resistance perpendicular to screw axis

$$R_d = \frac{k_{mod} \cdot R_k}{\gamma_M} \quad [N] \quad \gamma_M = 1.3$$

For determination of the characteristic value of the resistance, see §5.1

3.2 Design value of the withdrawal resistance

Design value of the resistance parallel to screw axis

Withdrawal resistance is determined by comparison of the design values of resistances corresponding with the three possible failure modes of SPAX screws.
The lowest value is retained.

$$R_{ax,d} = \min \begin{cases} \text{Design value of the resistance } R_{ax,d} \text{ based on failure in withdrawal of the threaded part} \\ \text{Design value of the resistance } R_{t,u,d} \text{ based on failure in tension of the steel} \\ \text{Design value of the resistance } R_{ax,d} \text{ based on failure in head pull-through} \end{cases}$$

Design value – Withdrawal of the threaded part:

$$R_{ax,d} = \frac{k_{mod} \cdot R_{ax,k}}{\gamma_M} \quad [N] \quad \gamma_M = 1.3 \quad \text{EC5 ; §2.4.3}$$

Design value – Steel tension:

$$R_{t,u,d} = \frac{R_{t,u,k}}{\gamma_M} \quad [N] \quad \gamma_M = 1.3$$

Design value – Head pull-through:

$$R_{ax,d} = \frac{k_{mod} \cdot R_{ax,k}}{\gamma_M} \quad [N] \quad \gamma_M = 1.3$$

4. Modification factors k_{mod}

4.1 Modification factor of the resistance k_{mod}

The modification factor of the resistance k_{mod} accounts for the influence of Service Class and load-duration class on the mechanical properties of wood or wood-based materials.

EC5 ; Tab. 3.1

The modification factor of the resistance k_{mod} is determined in 3 steps:

1. Determination of the Service Class
2. Determination of the load-duration class based on the most unfavourable load combination
3. Determination of the modification factor of the resistance k_{mod} based on the Service Class and load-duration class determined previously

Service Class

To account for the physical properties of wood based materials, wood based structures shall be assigned to a Service Class characterising the environmental conditions of the structure in service:

EC5 ; §2.3.1.3

Service Class 1: is characterised by a moisture content in wood based materials corresponding to a temperature of 20°C and the relative humidity of the surrounding air only exceeding 65% for a few weeks per year, e.g. a structure located in an interior heated environment.

Service Class 2: is characterised by a moisture content in wood based materials corresponding to a temperature of 20°C and the relative humidity of the surrounding air only exceeding 85% for a few weeks per year, e.g. an exterior but covered structure, protected from direct weathering.

Service Class 3: is characterised by climatic conditions leading to higher moisture contents than these of Service Class 2, e.g. for an exterior structure exposed to direct weathering.

Table 4.1 Summary of assignment to Service Classes

	A	B	C	D
1	SC	Surrounding climate ^a	Installation situation	Average moisture content u_{gl}
2	1	20 °C / Rel. Humidity ≤ 65 %	Interior heated	5 % – 15 % ^b
3	2	20 °C / Rel. Humidity ≤ 85 %	Exterior covered, protected from direct weathering	10 % – 20 % ^c
4	3	Moisture content higher than in SC2	Exterior, exposed to direct weathering	12 % – 24 %

Note:

Some configurations of exterior covered structures may however require to be assigned to SC3.

Members in exterior location may be assigned to SC2 provided they are adequately protected from direct weathering.

^a Conditions of the surrounding climate can be exceeded during a few weeks per year.

^b In SC1 the average moisture content of most softwoods will not exceed 12%.

^c In SC2 the average moisture content of most softwoods will not exceed 20%.

4. Modification factors k_{mod} and partial coefficient γ_M

4.1 Modification factor k_{mod}

Load-duration classes

Table 4.2 Assignment of actions to load-duration classes in accordance with BS EN 1991-1-1 and NA to BS EN 1995-1-1.

	A	B
1	Action	Load-duration class
2	Dead load per BS EN 1991-1-1 and its UK National Annex	
3	Imposed loads per BS EN 1991-1-1 and its UK National Annex	
4	A Areas for domestic and residential activities	Medium term
5	B Office areas	Medium term
6	C Areas where people may congregate (with the exception of areas defined under category A, B or D)	Medium term
7	D Shopping areas	Medium term
8	E Areas susceptible to accumulation of goods, including access areas	Long term
9	F Garages and vehicle traffic areas: gross vehicle weight ≤ 30 kN	Medium term
10	G Garages and vehicle traffic areas: $30 \text{ kN} < \text{gross vehicle weight} \leq 160 \text{ kN}$	Medium term
11	H Roofs non accessible except for normal maintenance and repair	Short term
12	K Roofs accessible for special services, such as helicopter landing areas	Short term
13	Horizontal loads per BS EN 1991-1-1 and its UK National Annex	
14	Horizontal loads on parapets and partition walls acting as barriers	Short term
15	Wind loading per BS EN 1991-1-4 and its UK National Annex	Instantaneous
16	Snow loading per BS EN 1991-1-3 and its UK National Annex	Short term

NA ; Tab. 2.2

Actions induced by differential set shall be assigned to Permanent load-duration class.

The influence of temperature changes can be neglected for wood based materials.

In case of a combination of actions assigned to different load-duration classes, the modification factor of the resistance k_{mod} corresponding to the shortest load-duration class may be used.

EC5 ; §3.1.3 (2)

4. Modification factors k_{mod} and partial coefficient γ_M

4.1 Modification factor k_{mod}

Table 4.3 Values of modification factor of the resistance k_{mod}

	A	B	C	D	E	F	G	H
1	Material	Standard	Service Class	Load-duration class				
				Permanent action	Long term action	Medium term action	Short term action	Instantaneous action
2	Solid timber	EN 14081-1	1	0.60	0.70	0.80	0.90	1.10
3			2	0.60	0.70	0.80	0.90	1.10
4			3	0.50	0.55	0.65	0.70	0.90
5	Glued laminated timber	EN 14080	1	0.60	0.70	0.80	0.90	1.10
6			2	0.60	0.70	0.80	0.90	1.10
7			3	0.50	0.55	0.65	0.70	0.90
8	Laminated veneer lumber (LVL)	EN 14374, EN14279	1	0.60	0.70	0.80	0.90	1.10
9			2	0.60	0.70	0.80	0.90	1.10
10			3	0.50	0.55	0.65	0.70	0.90
11	Plywood	EN 636						
12		Type EN 636-1	1	0.60	0.70	0.80	0.90	1.10
13		Type EN 636-2	2	0.60	0.70	0.80	0.90	1.10
14	OSB	Type EN 636-3	3	0.50	0.55	0.65	0.70	0.90
15		EN 300						
16		OSB/2	1	0.30	0.45	0.65	0.85	1.10
17	OSB	OSB/3, OSB/4	1	0.40	0.50	0.70	0.90	1.10
18		OSB/3, OSB/4	2	0.30	0.40	0.55	0.70	0.90
19	Particleboards	EN 312						
20		Type P4, Type P5	1	0.30	0.45	0.65	0.85	1.10
21		Type P5	2	0.20	0.30	0.45	0.60	0.80
22		Type P6, Type P7	1	0.40	0.50	0.70	0.90	1.10
23	Fibreboards, hard	Type P7	2	0.30	0.40	0.55	0.70	0.90
24		EN 622-2						
25		HB.LA, HB.HLA1 or 2	1	0.30	0.45	0.65	0.85	1.10
26	Fibreboards, medium	HB.HLA1 or 2	2	0.20	0.30	0.45	0.60	0.80
27		EN 622-3						
28		MBH.LA1 or 2	1	0.20	0.40	0.60	0.80	1.10
29	Fibreboards, MDF	MBH.HLS1 or 2	1	0.20	0.40	0.60	0.80	1.10
30		MBH.HLS1 or 2	2	–	–	–	0.45	0.80
31		EN 622-5						
32	Fibreboards, MDF	MDF.LA, MDF.HLS	1	0.20	0.40	0.60	0.80	1.10
		MDF.HLS	2	–	–	–	0.45	0.80

In case the connected members show different values of the modification factor of the resistance ($k_{mod,1}$ and $k_{mod,2}$), a single equivalent factor for the connection defined as follows may be used:

$$k_{mod} = \sqrt{k_{mod,1} \cdot k_{mod,2}}$$

EC5 ; Tab. 3.1

EC5 ; §2.3.2.1(2) Equ. (2.6)

4. Modification factors k_{mod} and partial coefficient γ_M

4.2 Partial coefficient for material properties γ_M

Table 4.5 Partial coefficient for material properties γ_M under static or quasi-static loading

	A	B
1	Material	γ_M
	Fundamental combinations:	
2	Solid timber, grade stamp individually marked	1.3
3	Solid timber, grade stamp package marked	2.0
4	Glued laminated timber	1.25
5	LVL, plywood, OSB	1.2
6	Particleboards	1.3
7	Fibreboards, hard	1.3
8	Fibreboards, medium	1.3
9	Fibreboards, MDF	1.3
10	Fibreboards, soft	1.3
11	Connections (except for punched metal plate fasteners)	1.3
12	Punched metal plate fasteners, anchorage strength	1.3
13	Punched metal plate fasteners, plate (steel) strength	1.15
14	Accidental combinations	1.0

EC5 ; §2.4.1(1) Tab. 2.3
+ NA §2.4.1(1)

For the design of steel parts, the partial coefficient for material properties defined in BS EN 1993-1-1 and its UK National Annex shall be used.

For accidental combinations of actions the partial coefficient value of γ_M shall be used.

5.1 Load-carrying capacity in shear

5.1.1 Design of SPAX timber connections in accordance with BS EN 1995-1-1, §8

The design of connections per Eurocode 5 considers the different failure modes depending on the embedment strength of the wood based members and on the yield moment of the fastener.

The characteristic value of shear resistance to Eurocode 5 of a connection with SPAX fasteners is determined by comparison of 6 failure modes:

EC5; 8.2.2 (1)

$$F_{v,Rk} = \min \left\{ \begin{array}{ll} f_{h,1,k} t_1 d_1 & (a) \\ f_{h,2,k} t_2 d_1 & (b) \\ \frac{f_{h,1,k} t_1 d_1}{1+\beta} \left[\sqrt{\beta+2\beta^2 \left[1 + \frac{t_2}{t_1} + \left(\frac{t_2}{t_1} \right)^2 \right] + \beta^3 \left(\frac{t_2}{t_1} \right)^2} - \beta \left(1 + \frac{t_2}{t_1} \right) \right] + \frac{F_{ax,\alpha,Rk}}{4} & (c) \\ 1.05 \frac{f_{h,1,k} t_1 d_1}{2+\beta} \left[\sqrt{2\beta(1+\beta) + \frac{4\beta(2+\beta)M_{y,Rk}}{f_{h,1,k} d_1 t_1^2}} - \beta \right] + \frac{F_{ax,\alpha,Rk}}{4} & (d) \\ 1.05 \frac{f_{h,1,k} t_1 d_1}{1+2\beta} \left[\sqrt{2\beta^2(1+\beta) + \frac{4\beta(1+2\beta)M_{y,Rk}}{f_{h,1,k} d_1 t_2^2}} - \beta \right] + \frac{F_{ax,\alpha,Rk}}{4} & (e) \\ 1.15 \sqrt{\frac{2\beta}{1+\beta}} \sqrt{2M_{y,Rk} f_{h,1,k} d_1} + \frac{F_{ax,\alpha,Rk}}{4} & (f) \end{array} \right.$$

$F_{v,Rk}$ = characteristic value of the embedment strength in shear + rope effect

where

$M_{y,Rk}$ = characteristic value of the yield moment of SPAX fasteners as defined in its ETA

$F_{ax,\alpha,Rk}$ = characteristic value of the resistance to head pull-through

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

with

$f_{h,1,k}$ = characteristic value of the embedment strength in member 1 (headside)

$f_{h,2,k}$ = characteristic value of the embedment strength in member 2 (pointside)

t_1 / t_2 = thickness of member 1 / penetration depth in member 2

The characteristic value of embedment strength $f_{h,k}$ is a contributor to the dowel bearing capacity of the wood based member, and is defined in Eurocode 5 as:

without predrilled holes:

$$f_{h,k} = 0.082 \cdot \rho_k \cdot d_1^{-0.3}$$

with predrilled holes:

$$f_{h,k} = 0.082 \cdot (1 - 0.01 \cdot d_1) \cdot \rho_k$$

where

ρ_k = characteristic density of wood member [kg/m³]

d_1 = outer thread diameter of SPAX [mm]

5.1 Load-carrying capacity in shear

5.1.1 Design of SPAX timber connections in accordance with BS EN 1995-1-1, §8

The embedding strength for screws in non-pre-drilled holes arranged at an angle between screw axis and grain direction, $0^\circ \leq \alpha \leq 90^\circ$ is:

$$f_{h,k} = \frac{0.082 \cdot \rho_k \cdot d^{-0.3}}{2.5 \cdot \cos^2 \alpha + \sin^2 \alpha} \quad [\text{MPa}]$$

for screws in pre-drilled holes:

$$f_{h,k} = \frac{0.082 \cdot \rho_k \cdot (1 - 0.01 \cdot d)}{2.5 \cdot \cos^2 \alpha + \sin^2 \alpha} \quad [\text{MPa}]$$

for threaded rods in pre-drilled holes:

$$f_{h,k} = \frac{0.082 \cdot \rho_k \cdot (1 - 0.01 \cdot d)}{(2.5 \cdot \cos^2 \alpha + \sin^2 \alpha) \cdot (k_{90} \cdot \sin^2 \varepsilon + \cos^2 \varepsilon)} \quad [\text{MPa}]$$

Where

- ρ_k characteristic timber density [kg/m^3];
- d outer thread diameter [mm];
- α angle between screw axis and grain direction;
- ε angle between force and grain direction;
- k_{90} according to equation (8.33) in EN 1995-1-1.

The embedding strength for screws arranged parallel to the plane of cross laminated timber, independent of the angle between screw axis and grain direction, $0^\circ \leq \alpha \leq 90^\circ$, shall be calculated from:

$$f_{h,k} = 20 \cdot d^{-0.5} \quad [\text{N/mm}^2]$$

unless otherwise specified in the technical specification (ETA or hEN) for the cross laminated timber.

Where

- d outer thread diameter [mm]
(d_i in the drawings in the annex)

The embedding strength for screws or threaded rods in the plane surface of cross laminated timber should be assumed as for solid timber based on the characteristic density of the outer layer. If relevant, the angle between force and grain direction of the outer layer should be taken into account.

The direction of the lateral force shall be perpendicular to the screw axis and parallel to the plane surface of the cross laminated timber.

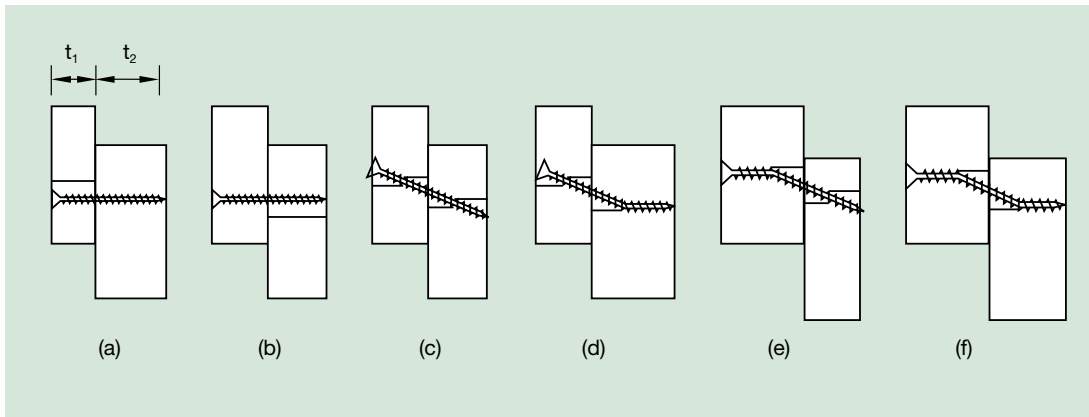
For angles $45^\circ \leq \alpha < 90^\circ$ between force and grain direction of the outer layer the characteristic load-carrying capacity may be assumed as 2/3 of the corresponding value for $\alpha = 90^\circ$, if only the penetration depth perpendicular to the wide face is taken into account.

ATE

5.1 Load-carrying capacity in shear

5.1.1 Design of SPAX timber connections in accordance with BS EN 1995-1-1, §8

Figure 5.1 Failure modes



a) embedment failure in member 1, (b) embedment failure in member 2, (c) embedment failure in members 1 and 2, (d) combined embedment and fastener yield failure in member 2, (e) combined embedment and fastener yield failure in member 1, (f) multiple yield failures of the fastener

Failure modes are correlated to the thickness of wood based members, influencing the embedment strength. The maximum load-carrying capacity of a connection in simple shear is reached when mode of failure (f) with multiple yield failures of the fastener governs. Defining a required minimum thickness of the wood based members (hence embedment strength) enables ensuring this failure mode.

The use of this required minimum thickness is advantageous in that it allows determining the load-carrying capacity in shear from one single equation instead of six. The required minimum thicknesses being based on the yield moment capacity of SPAX fasteners, they are obviously valid only for SPAX screws.

As shown in the following tables, the values of the required minimum thickness ensuring multiple yield failure as the governing failure mode are typically met or exceeded through the general design of the wood members.

5.1.2 Rope effect contribution ΔR_k

$$\Delta R_k = \min. \{F_{v,Rk} ; 0.25 \cdot F_{ax,\alpha,Rk}\}$$

For SPAX screws, the rope effect contribution can be taken into account up to 100% of the characteristic load-carrying capacity in shear (provided the characteristic withdrawal capacity is at least 4 times higher than the characteristic shear capacity).

Hence, the characteristic value of the shear resistance can be increased by up to 100% through contribution of the rope effect.

5.1 Load-carrying capacity in shear

5.1.3 Effective number of fasteners

When several (n) SPAX fasteners are aligned in a single row parallel to the grain, a reduced effective number of fasteners $n_{ef} = n^{kef}$ shall be taken into account. This reduction may be ignored ($n_{ef} = n$) provided the SPAX fasteners are driven home staggered by at least fastener diameter perpendicular to grain.

EC5 ; 8.3.1.1 (8)

Figure 5.2 Effective number of fasteners n_{ef}

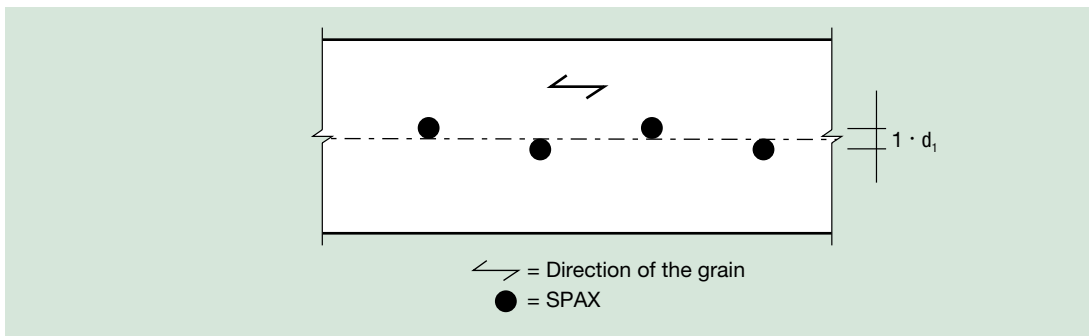


Table 5.1 Effective number of fasteners n_{ef} based on their spacing a_1 and predrilling conditions (with or without predrilled holes)

	A	B	C	D	E	F	G	H	I
1		effective number n_{ef}		effective number n_{ef}		effective number n_{ef}		effective number n_{ef}	
2		$k_{ef} = 0.5$		$k_{ef} = 0.7$		$k_{ef} = 0.85$		$k_{ef} = 1.0$	
3		$a_1 = 4 \cdot d_1$		$a_1 = 7 \cdot d_1$		$a_1 = 10 \cdot d_1$		$a_1 = 14 \cdot d_1$	
4		with predrilled holes		with predrilled holes, without predrilled holes		with predrilled holes, without predrilled holes		with predrilled holes, without predrilled holes	
5	n	$\alpha' = 0^\circ$	$\alpha' = 90^\circ$	$\alpha' = 0^\circ$	$\alpha' = 90^\circ$	$\alpha' = 0^\circ$	$\alpha' = 90^\circ$	$\alpha' = 0^\circ$	$\alpha' = 90^\circ$
6	1	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
7	2	1.4	2.0	1.6	2.0	1.8	2.0	2.0	2.0
8	3	1.7	3.0	2.2	3.0	2.5	3.0	3.0	3.0
9	4	2.0	4.0	2.6	4.0	3.2	4.0	4.0	4.0
10	5	2.2	5.0	3.1	5.0	3.9	5.0	5.0	5.0
11	6	2.4	6.0	3.5	6.0	4.6	6.0	6.0	6.0
12	7	2.6	7.0	3.9	7.0	5.2	7.0	7.0	7.0
13	8	2.8	8.0	4.3	8.0	5.9	8.0	8.0	8.0
14	9	3.0	9.0	4.7	9.0	6.5	9.0	9.0	9.0
15	10	3.2	10.0	5.0	10.0	7.1	10.0	10.0	10.0

EC5 ; Eq. (8.17)

5.2 Load-carrying capacity in withdrawal

The characteristic value of withdrawal resistance to Eurocode 5 of a connection with SPAX fasteners is determined by comparison of 3 failures modes:

- min. $\left\{ \begin{array}{l} 1 \text{ withdrawal failure of the threaded part in member 2 (pointside)} \quad \rightarrow \text{table 7.14} \\ 2 \text{ tensile failure } f_{\text{tens,k}} \text{ of SPAX steel} \quad \rightarrow \text{table 7.15} \\ 3 \text{ head pull-through failure in member 1 (headside), which is the maximum of the following modes:} \\ \quad \text{max. } \left\{ \begin{array}{l} \text{head pull-through} \quad \rightarrow \text{table 7.16} \\ \text{withdrawal failure of the threaded part in member 1 (headside)} \quad \rightarrow \text{table 7.14} \end{array} \right. \end{array} \right.$

The withdrawal resistance of the connection is the minimum of the design value of each if these three failure modes.

5.2.1 Characteristic value of withdrawal resistance of the threaded part $F_{\text{ax},\alpha,\text{Rk}}$

$$F_{\text{ax},\alpha,\text{Rk}} = \frac{n_{\text{ef}} \cdot f_{\text{ax},k} \cdot d_1 \cdot l_{\text{ef}}}{1.2 \cdot \cos^2 \alpha + \sin^2 \alpha} \cdot \left(\frac{\rho_k}{350} \right)^{0.8}$$

where

$F_{\text{ax},\alpha,\text{Rk}}$ characteristic withdrawal resistance of the screw at an angle α to the grain [N]

$n_{\text{ef}} \quad n_{\text{ef}} = n^{0.9} \quad \vee \quad n_{\text{ef}} = \max \{ n^{0.9} ; n \cdot 0.9 \}$

$f_{\text{ax},k}$ characteristic value of the withdrawal parameter

2.5 mm $\leq d \leq$ 5.0 mm: $f_{\text{ax},k} = 14.0 \text{ N/mm}^2$

6.0 mm $< d <$ 8.0 mm: $f_{\text{ax},k} = 12.0 \text{ N/mm}^2$

$d = 10.0 \text{ mm}$: $f_{\text{ax},k} = 11.5 \text{ N/mm}^2$

$d = 12.0 \text{ mm}$: $f_{\text{ax},k} = 11.0 \text{ N/mm}^2$

$d = 16.0 \text{ mm}$: $f_{\text{ax},k} = 10.0 \text{ N/mm}^2$

d_1 Outer thread diameter [mm]

(d_1 in the drawings in the annexes)

l_{ef} Penetration depth of the threaded part per BS EN 1995-1-1 [mm]

α Angle between the grain and the screw axis ($\alpha > 15^\circ$)

ρ_k Characteristic density [kg/m^3]

ETA

EC5 v ETA

ETA

5.2.2 Characteristic tensile resistance $f_{\text{tens,k}}$ of SPAX steel

The characteristic value of the tensile resistance $f_{\text{tens,k}}$ is defined in the ETA of SPAX screws.

See Table 7.15

The design value in accordance with EC5 is: $f_{\text{tens,d}} = f_{\text{tens,k}} / \gamma_M$

where $\gamma_M = 1.3$

5.2 Load-carrying capacity in withdrawal

5.2.3 Characteristic head pull-through capacity

Maximum of

$$\left\{ \begin{array}{l} n_{ef} \cdot f_{head,k} \cdot d_h^2 \cdot \left(\frac{\rho_k}{350} \right)^{0.8} \\ \frac{n_{ef} \cdot f_{ax,k} \cdot d_1 \cdot l_{ef}}{1.2 \cdot \cos^2 \alpha + \sin^2 \alpha} \cdot \left(\frac{\rho_k}{350} \right)^{0.8} \end{array} \right.$$

ETA

$f_{head,k}$ Characteristic value of the head pull-through parameter [N/mm²]

Table 5.2 Values of $f_{head,k}$ for timber connections

	A	B
1	Countersunk head	
2	d_h	$f_{head,k}$
3	≤ 16 mm	$27.0 - d_h$
4	$16 < d_h \leq 32$ mm	$11.0 - 0.2 \cdot (d_h - 16)$
5	Washer head, pan head, countersunk head with washer	
6	d_h	$f_{head,k}$
7	≤ 16 mm	$29 - d_h$
8	$16 \text{ mm} < d_h \leq 22$ mm	13.0
9	$22 \text{ mm} < d_h \leq 32$ mm	$16.0 - 0.5 \cdot (d_h - 16)$

d_h Diameter of screw head or washer [mm].
Outer diameter of screw head or washers
Nominal diameter is limited to 32 mm when $d_h > 32$ mm
(d_k defined in drawings of the ETA annexes).

ρ_k Characteristic density [kg/m³], for wood-based panels, use $\rho_k = 380$ kg/m³

5.2 Load-carrying capacity in withdrawal

5.2.4 Effective number of fasteners

The effective number of screws n_{ef} shall be used to account for the effect of a fastener group.

EC5 ; §8.7.2 (8)

$$n_{ef} = n^{0.9}$$

For axially loaded screws in tension, where the external force is parallel to the screw axes, the rules in EN 1995-1-1, 8.7.2 (8) should be applied.

ETA

For inclined screws in timber-to-timber or steel-to-timber shear connections, where the screws are arranged under an angle $30^\circ \leq \alpha \leq 60^\circ$ between the shear plane and the screw axis, the effective number of screws n_{ef} should be determined as follows:

For one row of n screws parallel to the load, the loadcarrying capacity should be calculated using the effective number of fasteners n_{ef} , where

$$n_{ef} = \max \{n^{0.9} ; 0.9 \cdot n\}$$

and n is the number of inclined screws in a row. If crossed pairs of screws are used in timber-to-timber connections, n is the number of crossed pairs of screws in a row.

Note: For screws as compression reinforcement or inclined screws as fasteners in mechanically jointed beams or columns or for the fixing of thermal insulation material, $n_{ef} = n$.

Table 5.3 Effective number of fasteners $n_{ef} = n^{0.9}$

	A	B	C	D	E	F	G	H	I	J	K	L
1	n	n_{ef}	n	n_{ef}	n	n_{ef}	n	n_{ef}	n	n_{ef}	n	n_{ef}
2	1	1.0	6	5.0	11	8.7	16	12.1	21	15.5	26	18.8
3	2	1.9	7	5.8	12	9.4	17	12.8	22	16.2	27	19.4
4	3	2.7	8	6.5	13	10.1	18	13.5	23	16.8	28	20.1
5	4	3.5	9	7.2	14	10.8	19	14.2	24	17.5	29	20.7
6	5	4.3	10	7.9	15	11.4	20	14.8	25	18.1	30	21.4

6. Installation guidelines

The German approval „allgemeine bauaufsichtliche Zulassung“ (AbZ) of SPAX screws contains prescriptions relative to state of the art installation of structural timber connections. As for the connection design, installation requirements of EC5 and its National Annex shall be considered as well, unless more restrictive prescriptions are stated in the AbZ.

In case of wood based members subject to a national or European approval, relevant installation prescriptions contained therein shall also be considered.

Installation guidelines aim at preventing premature splitting of the timber connection respectively of the considered wood member, before even reaching the load-carrying capacity determined for the designed configuration.

Hence, as an example, one should not misinterpret the minimum thickness t_{\min} defined thereafter with the required minimum thickness t_{req} . The required minimum thickness t_{req} is a prerequisite defined to simplify the design of screws subject to shear, ensuring that the multiple yield failure of screws is the governing failure mode.

6.1 General

Penetration depths $l_{\text{ef}} < 4 \cdot d_1$ shall not be considered in design, neither in shear, nor in withdrawal.	ETA
The screw thread is allowed to extend in the connected member.	ETA
Screws with countersunk head are permitted to be used with washers.	ETA
In case of reinforcement with full length threaded SPAX screws of a member subject to compression perpendicular at an angle $45^\circ \leq \alpha \leq 90^\circ$ to the grain, the uniform distribution of the compression stress to each reinforcing screw shall be ensured, and the capacity of the supporting material to resist the compression stress induced by the screw heads shall be verified. (select screws of identical length and a steel plate of appropriate thickness)	ETA, Annex C
In case of end grain fastening, solid timber moisture content shall not exceed 18% at the moment of installation.	Recommendation
Section reduction must be considered in member design. For SPAX screws the nominal diameter of the screw (outer thread diameter d_1) shall be used in absence of predrilled holes, while the predrilled hole diameter applies when otherwise. Section reduction does not need to be accounted for with SPAX screws of outer thread diameter $d_1 \leq 6$ mm driven without predrilling.	EC5 ; §5.2
In Douglas Fir or Maritime Pine, minimum fastener distances parallel to the grain shall be increased by 50%.	ETA
SPAX screws can be driven in softwoods without predrilled holes. When $d_1 \geq 8$ mm predrilled holes are required in species other than Spruce, Pine or Fir.	ETA

6. Installation guidelines


6.2 Predrilling

Softwoods: predrilling of wood members is allowed.
When $d_1 \geq 8$ mm, predrilled holes are required in species other than Spruce, Pine or Fir.

Hardwoods: predrilling of wood members **is mandatory**.

When predrilling wood members connected with SPAX screws, the table below lists recommended drill diameters.

Table 6.1 Recommended drill diameters for predrilling of wood members based on nominal diameter of SPAX screw

	A	B	C	D	E	F	G	H
1		Nominal $\emptyset d_1$ [mm]						
2		4.0	4.5	5.0	6.0	8.0	10.0	12.0
3	Softwoods	2.5	3.0	3.0	4.0	5.0	6.0	7.0
4	Hardwoods	3.0	3.0	3.5	4.0	6.0	7.0	8.0

Complementary information relative to this topic can be found in the technical note SPAX Holzbau-Report n° 6.
Hardwoods can be: Beech or Oak solid timber, Beech, Oak or Ash glued laminated timber in accordance with their European or national approval.

Complementary installation guidelines:

Holes in steel parts must be predrilled with appropriate diameter.

Holes in fibre cement boards must be predrilled with $0.7 \cdot d_1$ diameter.

SPAX screws with countersunk head require steel parts and fibre cement boards with appropriate countersunk.

6.3 Minimum thickness t_{min} to prevent wood splitting.

In order to prevent splitting, wood members in connections with nails or screws without predrilled holes, shall meet or exceed a minimum thickness t_{min} .

Provided the minimum spacing, end and edge distances prescribed in Table 8.2 of EC5 (see Table 6.3, C-E) are met, the minimum thicknesses are:

Softwood timber
$$t_{min} = \max \left\{ 14 \cdot d_1 ; (13 \cdot d_1 - 30) \cdot \frac{\rho_k}{200} \right\}$$

Pine timber
$$t_{min} = \max \left\{ 7 \cdot d_1 ; (13 \cdot d_1 - 30) \cdot \frac{\rho_k}{400} \right\}$$

As SPAX screws with 4CUT or CUT point reduce significantly the risk of splitting, the prescribed minimum thicknesses may be reduced as well.

See Table 6.3 for these prescriptions.

Prescribed minimum thicknesses do not apply to members with predrilled holes.

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EC5 ; §8.3.1.2

EC5 ; Eq. (8.19)

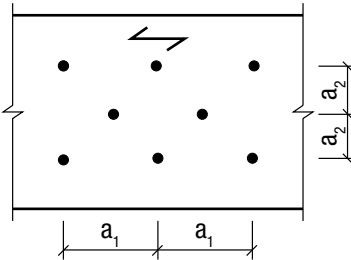
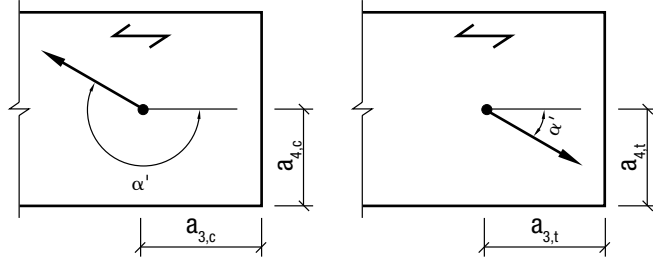
EC5 ; Eq. (8.18)

ETA

6. Installation guidelines

6.4 Minimum spacing, end and edge distances

Table 6.2 Definition of minimum spacing, end and edge distances per EC5 and ETA of SPAX screws


1	A	B
		EC5 resp. SPAX [®]
2		
		
3	spacing parallel to the grain $0^\circ \leq \alpha' \leq 360^\circ$	a_1
4	spacing perpendicular to the grain $0^\circ \leq \alpha' \leq 360^\circ$	a_2
5	loaded end distance $-90^\circ \leq \alpha' \leq 90^\circ$	$a_{3,t}$
6	unloaded end distance $90^\circ \leq \alpha' \leq 270^\circ$	$a_{3,c}$
7	loaded edge distance $0^\circ \leq \alpha' \leq 180^\circ$	$a_{4,t}$
8	unloaded edge distance $180^\circ \leq \alpha' \leq 360^\circ$	$a_{4,c}$

EC5 ; Figure 8.7
ETA

6. Installation guidelines

6.4 Minimum spacing, end and edge distances

Table 6.3 a Minimum spacing, end and edge distances of wood to wood connections in shear or combined shear and withdrawal per EC5

	A	B	C	D	E
1			Shear or withdrawal or combined shear and withdrawal		
2			Minimum spacing, end and edge distances per EC5, Table 8.2		
3					Without minimum thickness requirement as with predrilled holes
4					
5			SPAX screw $d_1 \leq 6$ mm: see Table 6.3b C2-C5 or D2-D5, SPAX screw $d_1 \geq 8$ mm: see Table 6.3b E2-E5		
6			without predrilled holes		with predrilled holes
7			$\rho_k \leq 420 \text{ kg/m}^3$	$420 \text{ kg/m}^3 < \rho_k < 500 \text{ kg/m}^3$	
8	a_1	spacing parallel to the grain $0^\circ \leq \alpha' \leq 360^\circ$	$d_1 < 5 \text{ mm} :$ $(5 + 5 \mid \cos \alpha' \mid) \cdot d_1$	$(7 + 8 \mid \cos \alpha' \mid) \cdot d_1$	$(4 + \mid \cos \alpha' \mid) \cdot d_1$
9			$d_1 \geq 5 \text{ mm} :$ $(5 + 7 \mid \cos \alpha' \mid) \cdot d_1$		
10	a_2	spacing perpendicular to the grain $0^\circ \leq \alpha' \leq 360^\circ$	$5 \cdot d_1$	$7 \cdot d_1$	$(3 + \mid \sin \alpha' \mid) \cdot d_1$
11	$a_{3,t}$	loaded end distance $-90^\circ \leq \alpha' \leq 90^\circ$	$(10 + 5 \cos \alpha') \cdot d_1$	$(15 + 5 \cos \alpha') \cdot d_1$	$(7 + 5 \cos \alpha') \cdot d_1$
12					
13	$a_{3,c}$	unloaded end distance $90^\circ \leq \alpha' \leq 270^\circ$	$10 \cdot d_1$	$15 \cdot d_1$	$7 \cdot d_1$
14	$a_{4,t}$	loaded edge distance $0^\circ \leq \alpha' \leq 180^\circ$	$d_1 < 5 \text{ mm} :$ $(5 + 2 \cdot \sin \alpha') \cdot d_1$	$d_1 < 5 \text{ mm} :$ $(7 + 2 \cdot \sin \alpha') \cdot d_1$	$d_1 < 5 \text{ mm} :$ $(3 + 2 \cdot \sin \alpha') \cdot d_1$
15			$d_1 \geq 5 \text{ mm} :$ $(5 + 5 \cdot \sin \alpha') \cdot d_1$	$d_1 \geq 5 \text{ mm} :$ $(7 + 5 \cdot \sin \alpha') \cdot d_1$	$d_1 \geq 5 \text{ mm} :$ $(3 + 4 \cdot \sin \alpha') \cdot d_1$
16	$a_{4,c}$	unloaded edge distance $180^\circ \leq \alpha' \leq 360^\circ$	$5 \cdot d_1^a)$	$7 \cdot d_1^a)$	$3 \cdot d_1$

α' = angle between applied force and direction of the grain

A_{\min} = minimum section (area) of connected wood members

In Douglas Fir and Maritime Pine, minimum spacing and distances parallel to the grain shall be increased by 50%.

^{a)} For SPAX screws: $a_{4,c} = 3 \cdot d_1$ may be used provided a_1 and $a_{3,t}$ are met and $a_{3,c} \geq 25 \cdot d_1$


For steel to wood connections:

minimum spacing a_1 and a_2 may be multiplied by 0.7.

6. Installation guidelines

6.4 Minimum spacing, end and edge distances

Table 6.3 b Minimum spacing, end and edge distances of wood to wood connections in shear or combined shear and withdrawal per §4.2.4 of the ETA of SPAX screws

	A	B	C	D	E	F
1			Shear or withdrawal or combined shear and withdrawal			Withdrawal
2			$A_{min} \geq 40 \cdot d_1^2$			
3			$SPAX \ d_1 \leq 6 \text{ mm}$		$SPAX \ d_1 \geq 8 \text{ mm}$	$SPAX \ d_1 \leq 12 \text{ mm}$
4			4CUT point	CUT point	4CUT or CUT point	4CUT or CUT point ^{b)}
5			$t_{min} = \max \begin{cases} 6 \cdot d_1 \\ 20 \text{ mm} \end{cases}$	$t_{min} = \max \begin{cases} 5 \cdot d_1 \\ 20 \text{ mm} \end{cases}$	$t_{min} = 7 \cdot d_1$	$t_{min} = 12 \cdot d_1$ pour Kerto-Q et Kerto-S $t_{min} = 6 \cdot d_1$
6			without predrilled holes	without predrilled holes	without predrilled holes	without predrilled holes
7						
8	a_1	spacing parallel to the grain $0^\circ \leq \alpha' \leq 360^\circ$	$5 \cdot d_1$			$5 \cdot d_1$
9						
10	a_2	spacing perpendicular to the grain $0^\circ \leq \alpha' \leq 360^\circ$	$(3 + \sin \alpha') \cdot d_1$			$5 \cdot d_1$ resp. $2,5 \cdot d_1$ (when $a_1 \cdot a_2 = 25 \cdot d_1^2$)
11	$a_{3,t}$	loaded end distance $-90^\circ \leq \alpha' \leq 90^\circ$	$12 \cdot d_1$			c)
12						
13	$a_{3,c}$	unloaded end distance $90^\circ \leq \alpha' \leq 270^\circ$	$12 \cdot d_1$			$5 \cdot d_1$
14	$a_{4,t}$	loaded edge distance $0^\circ \leq \alpha' \leq 180^\circ$	$d_1 < 5 \text{ mm} :$ $(3 + 2 \cdot \sin \alpha') \cdot d_1$			c)
15			$d_1 \geq 5 \text{ mm} :$ $(3 + 4 \cdot \sin \alpha') \cdot d_1$			
16	$a_{4,c}$	unloaded edge distance $180^\circ \leq \alpha' \leq 360^\circ$	$3 \cdot d_1$			$3 \cdot d_1$

ETA

A_{min} = minimum section (area) of connected wood members

In Douglas Fir and Maritime Pine, minimum spacing and distances parallel to the grain shall be increased by 50%.

^{b)} Specific point shape is required for Kerto-Q and Kerto-S

^{c)} In case of SPAX screws designed for withdrawal exclusively, all ends and edges can be considered unloaded.

For steel to wood connections:

minimum spacing a_1 and a_2 may be multiplied by 0.7.

6. Installation guidelines

6.4 Minimum spacing, end and edge distances for SPAX screws loaded axially

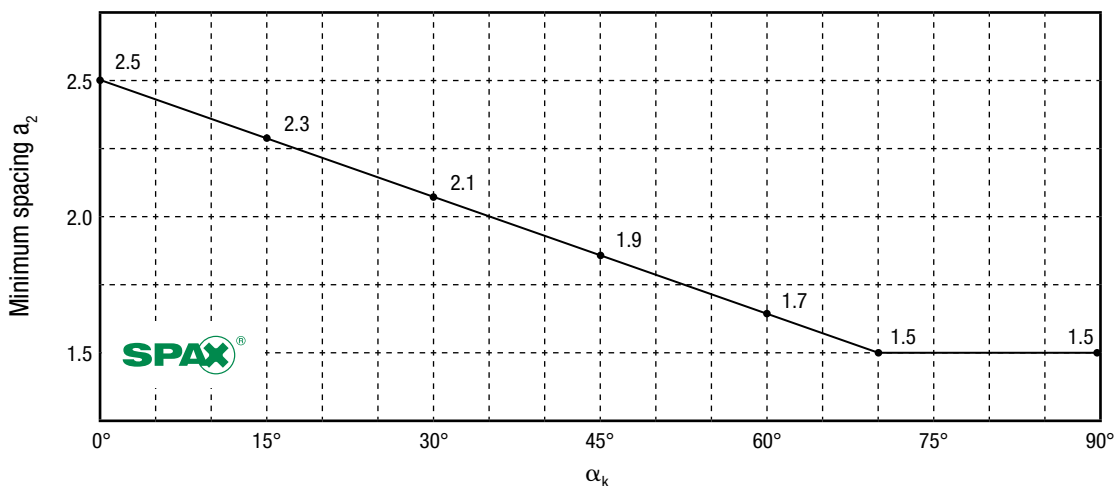
For crosswise installed screws, minimum spacing a_2 can be taken as:

$$a_2 = \max \begin{cases} 1.5 \cdot d_1 \\ 2.5 \cdot \left(1 - \frac{\alpha_k}{180^\circ}\right) \cdot d_1 \quad \text{with } 0^\circ \leq \alpha_k \leq 90^\circ \end{cases}$$

α_k = angle between crosswise installed screws

Subsequent parallel screws of neighbouring crosswise installed screw pairs shall meet the minimum spacing a_1 and a_2 .

Diagram 6.1 Minimum spacing a_2 based on angle α_k between crosswise installed screws

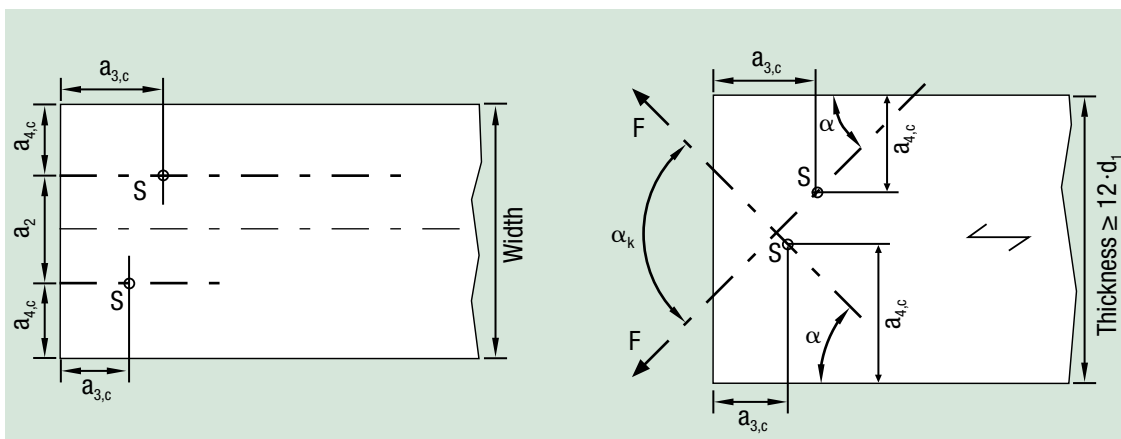


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Figure 6.1 Crosswise configuration (e.g. for one pair of screws)

Plan view

Side view



S = Centre of gravity of the threaded part penetrating the wood member.

In case of predrilled holes, the requirement for minimum thickness $\geq 12 \cdot d_1$ does not apply.

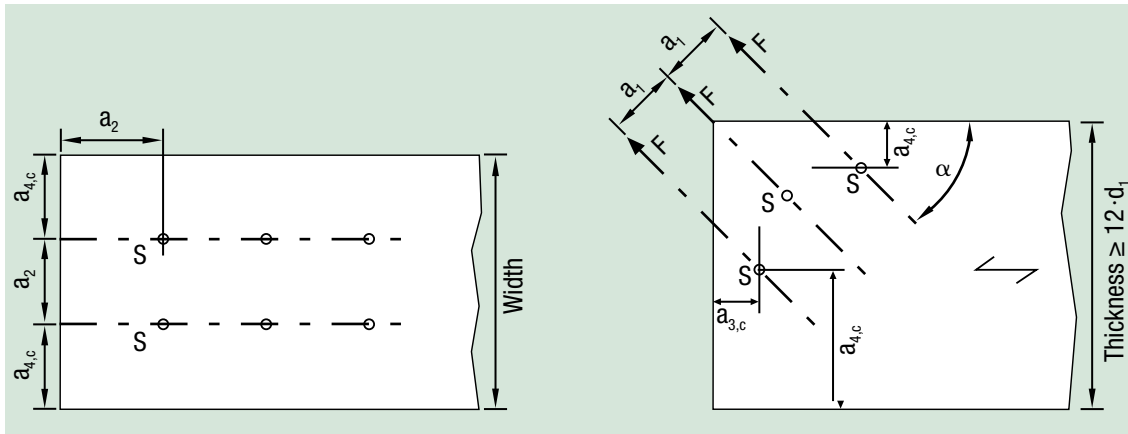
6. Installation guidelines

6.4 Minimum spacing, end and edge distances for SPAX screws loaded axially

Figure 6.2 Parallel configuration (e.g. for 3 pairs of screws)

Plan view

Side view




S = Centre of gravity of the threaded part penetrating the wood member.

In case of predrilled holes, the requirement for minimum thickness $\geq 12 \cdot d_1$ does not apply.

7. Shear: wood to wood

Minimum required penetration depth

Table 7.2 Minimum required thickness $t_{1,req}$ resp. penetration depth $t_{2,req}$ for wood to wood connections without predrilled holes, with wood materials of identical density ($\beta = 1$) and $t_{1,req} = t_{2,req}$ [mm], applicable to SPAX screws made from high-carbon steel


	A	B	C	D	E	F	G	H	I	J
1				Nominal diameter d_1 [mm]						
2	Strength class		ρ_k [kg/m³]	4.0	4.5	5.0	6.0	8.0	10.0	12.0
3	C16		310	28	31	35	41	54	66	79
4	C24	GL24c	350	26	30	33	39	51	62	74
5	C30	GL24h, GL28c	380	25	28	31	37	49	60	71
6	C35		400	25	28	31	36	47	58	69
7		GL28h, GL32c	410	24	27	30	36	47	58	69
8	C40		420	24	27	30	35	46	57	68
9		GL32h, GL36c	430	24	27	29	35	46	56	67
10		GL36h	450	23	26	29	34	45	55	65

In accordance with German National Annex to EC5:

In case the thickness t_1 resp. t_2 is less than the minimum required thickness $t_{1,req}$ resp. $t_{2,req}$, it is permitted to determine the characteristic load-carrying capacity in shear $F_{v,Rk}$ by multiplying the listed value of $F_{v,Rk}$ by the minimum of ratio $t_1/t_{1,req}$ and $t_2/t_{2,req}$.

DIN NA ; §8.2.4 (NA.2)


Table 7.2 a Adjustment factor for SPAX screws made from other steel grade

	A	B	C	D	E	F	G	H
1								
2	Nominal diameter d_1 [mm]							
3	Stainless steel	0.846	0.839	0.839	0.833	0.830	0.828	0.831
4	with predrilled holes	0.846	0.839	0.828	0.806	0.766	0.759	0.743

7. Shear: wood to wood

Load-carrying capacity


Table 7.3 Characteristic load-carrying capacity in single shear per shear plane $F_{v,Rk}$ for wood to wood connections without predrilled holes [N] applicable to SPAX screws made from high-carbon steel

	A	B	C	D	E	F	G	H	I	J
1			Nominal diameter d_i [mm]							
2	Strength class		ρ_k [kg/m ³]	4.0	4.5	5.0	6.0	8.0	10.0	12.0
3	C16		310	766	931	1,107	1,496	2,404	3,475	4,694
4	C24	GL24c	350	814	989	1,176	1,589	2,555	3,692	4,988
5	C30	GL24h, GL28c	380	848	1,030	1,226	1,656	2,662	3,847	5,197
6	C35		400	870	1,057	1,258	1,699	2,731	3,947	5,332
7		GL28h, GL32c	410	881	1,070	1,273	1,720	2,765	3,996	5,399
8	C40		420	892	1,083	1,289	1,741	2,799	4,045	5,464
9		GL32h, GL36c	430	902	1,096	1,304	1,762	2,832	4,092	5,529
10		GL36h	450	923	1,121	1,334	1,802	2,867	4,186	5,656

EC5; Eq. (8.6 f)

$n_{ef} \rightarrow$ 5.1.3 Effective number of fasteners

Table 7.3 a Adjustment factor for SPAX screws made from other steel grade

	A	B	C	D	E	F	G	H
1								
2	Nominal diameter d_i [mm]							
3		4.0	4.5	5.0	6.0	8.0	10.0	12.0
4	Stainless steel	0.816	0.816	0.816	0.816	0.816	0.816	0.816
5	with predrilled holes	1.206	1.223	1.240	1.268	1.310	1.340	1.362

It is permitted to select the characteristic embedment strength $f_{h,k}$ corresponding to the highest value of the characteristic density ρ_k of each connected wood material.

DIN NA ; §8.3.1.2

ΔR_k - In single shear, the characteristic load-carrying capacity R_k shall be increased by the rope effect contribution ΔR_k .

$$\Delta R_k = \min \{ F_{v,Rk} ; 0.25 \cdot F_{ax,\alpha,k} \}$$


EC5 ; §8.2.2 (2)

See overleaf for complementary information relative to $\Delta R_k = 0.25 \cdot F_{ax,\alpha,k} \rightarrow$

7. Shear: wood to wood

Load-bearing capacity

Table 7.3 b values of $\Delta R_k = 0,25 \cdot F_{ax,\alpha,Rk}$ [N] for failure in head pull-through depending on the screw head geometry

	A	B	C	D	E	F	G	H	I
1			Nominal diameter d_t [mm]						
2			4.0	4.5	5.0	6.0	8.0	10.0	12.0
3			Flat countersunk head d_k [mm]						
4	Strength class		8.0	8.8	9.7	11.6	15.1	18.6	22.6
5	C24	GL24c	304	352	407	518	678	906	1,236
6	C30	GL24h, GL28c	325	376	435	553	724	968	1,320
7	C35		338	392	453	576	755	1,009	1,375
8		GL28h, GL32c	345	400	462	588	770	1,029	1,403
9	C40		352	408	471	599	785	1,049	1,430
10		GL32h, GL36c	358	415	480	611	800	1,069	1,457
11		GL36h	372	431	498	633	829	1,108	1,511
12	with $l_{ef,k} \leq$ [mm]		22	22	23	29	28	32	37
13	with $l_{ef} >$ [mm]		22	22	23	29	32	40	48
14			Washer head d_k [mm]						-
15			9.6	10.6	11.6	13.6	20.0	25.0	
16	C24	GL24c	447	517	585	712	1,300	1,797	
17	C30	GL24h, GL28c	477	552	625	761	1,388	1,919	
18	C35		497	575	651	792	1,447	1,999	
19		GL28h, GL32c	507	587	664	808	1,475	2,039	
20	C40		517	598	677	824	1,504	2,079	
21		GL32h, GL36c	527	609	690	840	1,533	2,119	
22		GL36h	547	632	716	871	1,589	2,197	
23	with $l_{ef,k} \leq$ [mm]		32	33	33	40	54	63	
24	with $l_{ef} >$ [mm]		32	33	33	40	54	63	

When the effective threaded length $l_{ef,k}$ headside or l_{ef} pointside is larger than the tabulated length, a higher value of ΔR_k can be determined and taken into account.

For full threaded screws with larger values of the effective threaded lengths $l_{ef,k}$ and l_{ef} a higher value of ΔR_k can be determined and taken into account.

7. Withdrawal

Characteristic withdrawal resistance of the threaded part $F_{ax, \alpha, Rk}$

Table 7.14 Characteristic withdrawal resistance $F_{ax, \alpha, Rk}$ at an angle $\alpha = 90^\circ$ between screw axis and direction of the grain [N per mm of effective threaded length l_{ef}], applicable to SPAX screws made from high-carbon or stainless steel

	A	B	C	D	E	F	G	H	I	J
1	SPAX [®]			Nominal diameter d , [mm]						
2	Strength class		ρ_k [kg/m ³]	4.0	4.5	5.0	6.0	8.0	10.0	12.0
3	C16		310	50.8	57.2	63.5	65.3	87.1	104.4	119.8
4	C24	GL24c	350	56.0	63.0	70.0	72.0	96.0	115.0	132.0
5	C30	GL24h, GL28c	380	59.8	67.3	74.8	76.9	102.5	122.8	141.0
6	C35		400	62.3	70.1	77.9	80.1	106.8	128.0	146.9
7		GL28h, GL32c	410	63.6	71.5	79.4	81.7	109.0	130.5	149.8
8	C40		420	64.8	72.9	81.0	83.3	111.1	133.1	152.7
9		GL32h, GL36c	430	66.0	74.3	82.5	84.9	113.2	135.6	155.6
10		GL36h	450	68.5	77.0	85.6	88.0	117.4	140.6	161.4

$n_{ef} \rightarrow$ 5.2.4 Effective number of fasteners

Diagram 7.1 Adjustment factor k_{ax} for angle α between screw axis and direction of the grain

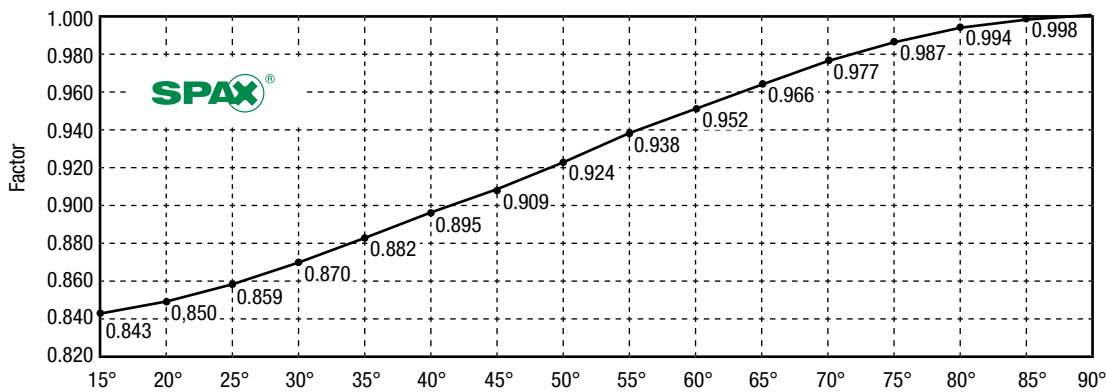


Diagram shows:
$$\frac{1}{1.2 \cdot \cos^2 \alpha + \sin^2 \alpha}$$

Table 7.15 Characteristic and design values of the steel tensile resistance [N] applicable to SPAX screws made from high-carbon or stainless steel


	A	B	C	D	E	F	G	H	I
1	SPAX [®]		d , [mm]						
2			4.0	4.5	5.0	6.0	8.0	10.0	12.0
3	High-carbon steel	$f_{tens,k}$	5,000	6,400	7,900	11,000	17,000	28,000	38,000
4		$f_{tens,d}$	3,846	4,923	6,077	8,462	13,077	21,538	29,231
5	Stainless steel	$f_{tens,k}$	3,800	4,200	4,900	7,100	13,000	20,000	28,000
6		$f_{tens,d}$	2,923	3,231	3,769	5,462	10,000	15,385	21,538

The maximum axial solicitation (withdrawal) of SPAX screws is limited by the design value of the steel tensile resistance $f_{tens,d}$.

7. Withdrawal


Characteristic resistance to head pull-through

Table 7.16 Characteristic resistance to head pull-through $F_{ax,\alpha,Rk}$ [N]
applicable to SPAX screws made from **high-carbon or stainless steel**

	A	B	C	D	E	F	G	H	I	J
1			d _i [mm]							
2			4.0	4.5	5.0	6.0	8.0	10.0	12.0	
3									Partial thread	Full thread
4	Countersunk head		d _h [mm]							
5			8.0	8.8	9.7	11.6	15.1	18.6	22.6	18.6
6	Wood	ρ _k = 350 kg/m³	1,216	1,409	1,628	2,072	2,713	3,626	4,944	3,626
7	Wood based panels	ρ _k = 380 kg/m³	1,299	1,505	1,738	2,213	2,898	3,872	5,280	3,872
8	for wood based panels of thickness t ≤ 20mm:									
9	12 mm ≤ t ≤ 20 mm		547	662	804	1,150	1,948	2,956	4,364	2,956
10	t < 12 mm		400					-		
11	Washer head		d _h [mm]							
12			9.6	10.6	11.6	13.6	20.0	25.0	-	
13	Wood	ρ _k = 350 kg/m³	1,788	2,067	2,341	2,848	5,200	7,188	-	
14	Wood based panels	ρ _k = 380 kg/m³	1,909	2,208	2,501	3,042	5,554	7,676	-	
15	for wood based panels of thickness t ≤ 20mm:									
16	12 mm ≤ t ≤ 20 mm		787	960	1,150	1,580	3,418	5,340	-	
17	t < 12 mm		400					-		
18	Washer		d [mm]							
19			-				25	32	40 ¹⁾	
20	Wood	ρ _k = 350 kg/m³	-				7,188	8,192	8,192	
21	Wood based panels	ρ _k = 380 kg/m³					7,676	8,749	8,749	
22	for wood based panels of thickness t ≤ 20mm:									
23	12 mm ≤ t ≤ 20 mm		-				5,340	8,749	8,749	
24	t < 12 mm						400			

¹⁾ Use a nominal diameter value of 32 mm when $d_h > 32 \text{ mm}$.

Table 7.16a Adjustment factor for resistance to head pull-through based on characteristic density for wood to wood connection per table 7.16

	A	B	C	D	E	F	G	H	H
1		ρ_k [kg/m ³]							
2		310	350	380	400	410	420	430	450
3		0.907	1.000	1.068	1.113	1.135	1.157	1.179	1.223

Characteristic density ρ_k is limited to 380 kg/m³ for wood based panel to wood connections.

Head pull-through does not apply to steel to wood connections.

8. Overview of product offering

Tables thereafter only present a limited overview of the SPAX product offering. Other references, geometries and dimensions are available at www.spax.com → Screw finder

Description and dimensions

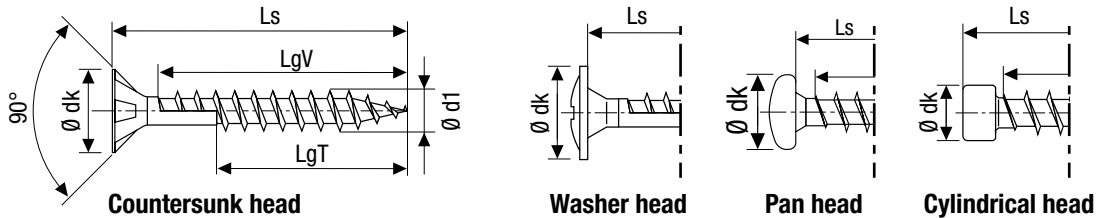


Table 8.1 Full thread

	A	B	C	D	E	F	G
1	Full thread					Full thread	
2	High-carbon steel					Stainless steel	
3	ETA-12/0114					ETA-12/0114	
4	d_1	6.0	8.0	10.0	12.0	10.0	12.0
5	Head geometry	Cylindrical head		Countersunk head		Countersunk head	
6	d_k	8.4	10.0	15.1	18.6	18.6	18.6
7	Point	4CUT point	CUT point	CUT point	CUT point	CUT point	CUT point
8	Length increment L_s	L_s					L_s
9	every 20mm	80 - 200	200 - 300	160 - 300	200 - 300	200, 240, 280, 300	160, 200 - 300
10	every 50mm	-	350 - 450	350 - 600	350 - 600	350 - 600	350 - 400
11				800			400 - 550

Table 8.2 Pan head

	A	B	C	D	E	F	G
1	High-carbon steel					Stainless steel	
2	Pan head					Pan head	
3	ETA-12/0114					ETA-12/0114	
4	d_1	4.0	4.5	5.0	6.0	4.0	5.0
5	d_k	8.0	9.0	9.9	11.9	8.0	9.9
6	Point	4CUT point	4CUT point	4CUT point	4CUT point	4CUT point	4CUT point
7	L_s	l_g	l_g	l_g	l_g	l_g	l_g
8	20	18				16	
9	25	23	22	22		21	20
10	30	27	27	27	27	25	25
11	35	32	32	32	32	30	
12	40	37	37	37	37	35	35
13	45	42	42	41	41	40	
14	50	47	47	46	46	45	44
15	60	50	57	56	56		
16	70			61	61		
17	80			61	61		
18	90			61	61		
19	100				61		

l_g = threaded length

For SPAX screws of thread diameter $d_1 < 4.0$ mm, refer to AbZ Z-9.1-235 or ETA-12/0114.

8. Overview of product offering

Table 8.3 Countersunk head of high-carbon steel

	A	B	C	D	E	F	G	H	I	J	K	L
1	High-carbon steel											
2	Countersunk head											
3		ETA-12/0114						ETA-12/0114				
4	d ₁	4.0		4.5		5.0		6.0		8.0	10.0	12.0
5	d _k	8.0		8.8		9.7		11.6		15.1	18.6	22.6
6	Point	4CUT point		4CUT point		4CUT point		4CUT point		4CUT point	4CUT point	
7	Ls	lgV	lgT	lgV	lgT	lgV	lgT	lgV	lgT	lgT	lgT	lgT
8	20	16										
9	25	21		20		20						
10	30	25	18	25		25		24				
11	35	30	23	30	25	30	25	29				
12	40	35	23	34	25	35	27	34	24			
13	45	40	30	39	30	39	30	38				
14	50	45	32	44	32	44	32	43	32			
15	55	50	32	49	37	49	37	48				
16	60	50	35	54	37	54	37	53	37			
17	70	50	37	59	42	61	41	61	41			
18	80	50	37	59	47	61	46	61	46	47	50	
19	90						61		61			
20	100						61		61	57	60	60
21	110						69		68			
22	120						69		68	70	70	80
23	130								68			
24	140								68	80	80	80
25	150								68			
26	160								65	80	80	100
27	180								65	80	80	100
28	200								65	80	80	100
29	220								65	80	80	100
30	240								65	80	80	100
31	260								65	80	80	100
32	280								65	80	80	100
33	300								65	80	80	100
34	320									80	80	
35	340									80	80	
36	350											100
37	360									80	80	
38	380									80	80	
39	400									80	80	100
40	450									80	80	100
41	500											100
42	550											100
43	600											100

lgV = full thread

lgT = partial thread

For SPAX screws of thread diameter d₁ < 4.0 mm, refer to AbZ Z-9.1-235 or ETA-12/0114.

8. Overview of product offering

Table 8.4 a Countersunk head of stainless steel

	A	B	C	D	E	F	G	H	I
1	Stainless steel								
2	Countersunk head								
3	ETA-12/0114								
4	d ₁	4.0		4.5		5.0		6.0	
5	d _k	8.0		8.8		9.7		11.6	
6	Point	4CUT point		4CUT point		4CUT point		4CUT point	
7	Ls	lgV	lgT	lgV	lgT	lgV	lgT	lgV	lgT
8	20	16							
9	25	21		20					
10	30	25	18	25		25			
11	35	30	23	30	25	30			
12	40	35	23	34	25	35	27	34	
13	45	40	30	39	30	39	30		
14	50	45	32	44	32	44	32	43	
15	60	50		54	37	54	37	53	37
16	70			59	42	61	41	61	41
17	80					61	46	61	46
18	90						61		61
19	100						61		61
20	120						69		68
21	140								68
22	160								65

lgV = full thread

lgT = partial thread

Table 8.4 a Countersunk head of stainless steel with CUT point

	A	B	C	D	E
1	Stainless steel				
2	Countersunk head				
3	ETA-12/0114				
4	d ₁	4.5		5.0	
5	d _k	8.8		9.7	
6	Point	4CUT point		4CUT point	
7	Ls	lgT		lgT	
8	35	25			
9	40	25			
10	45	30			
11	50	32			
12	60	37		37	
13	70	42		52	
14	80			61	

lgT = partial thread

8. Overview of product offering

Table 8.5 Washer head

	A	B	C	D	E	F	G	H
1	High-carbon steel							Stainless steel
2	Flange head resp. washer head							Washer head
3		ETA-12/0114				ETA-12/0114		ETA-12/0114
4	d ₁	4.0	4.5	5.0	6.0	8.0	10.0	8.0
5	d _k	9.6	10.6	11.6	13.6	20.0	25.0	20.0
6	Point	4CUT point	4CUT point	4CUT point	4CUT point	4CUT point	4CUT point	4CUT point
7	L _s	lg	lg	lg	lg	lg	lg	lg
8	20	18						
9	25	23	22	22				
10	30	27	27	27				
11	35	32	32	32				
12	40	37	37	37				
13	45	42	42	41				
14	50		47	46		46		46
15	60			56	56			56
16	80				61	70	70	70
17	100				61	80	80	80
18	120				68	80	80	80
19	140				68	80	80	80
20	160				65	80	80	80
21	180				65	80	80	80
22	200					80	80	80
23	220					80	80	
24	240					80	80	
25	260					80	80	
26	280					80	80	
27	300					80	80	
28	320					80	80	
29	340					80	80	
30	360					80	80	
31	380					80	80	
32	400					80	80	
33	450					80	80	

lg = threaded length

For SPAX screws of thread diameter d₁ < 4.0 mm, refer to AbZ Z-9.1-235 or ETA-12/0114.

8. Overview of product offering

Figure 8.1 Washers for countersunk head screws

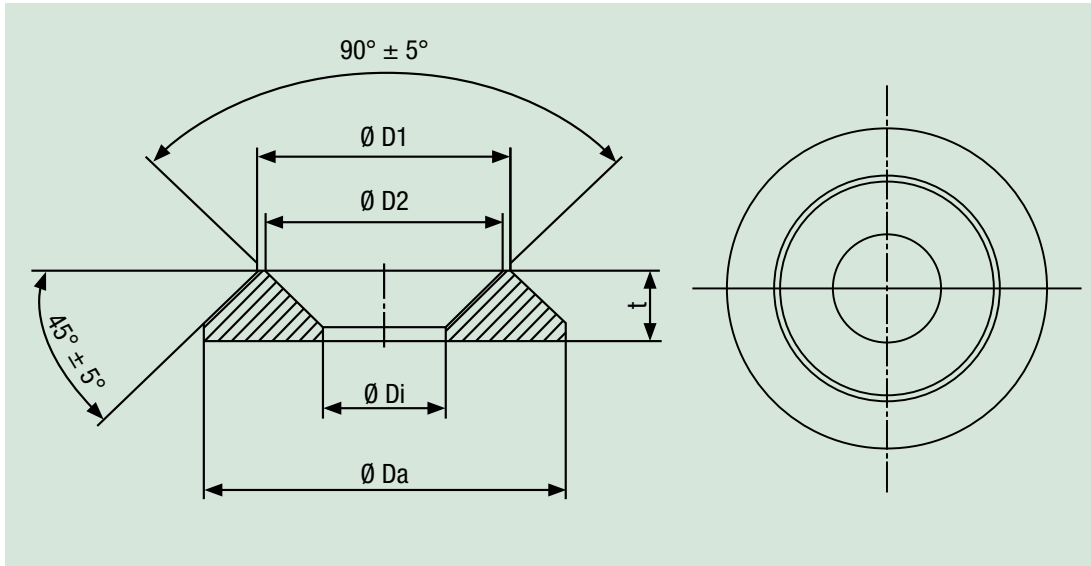


Table 8.6 Washers for countersunk head screws

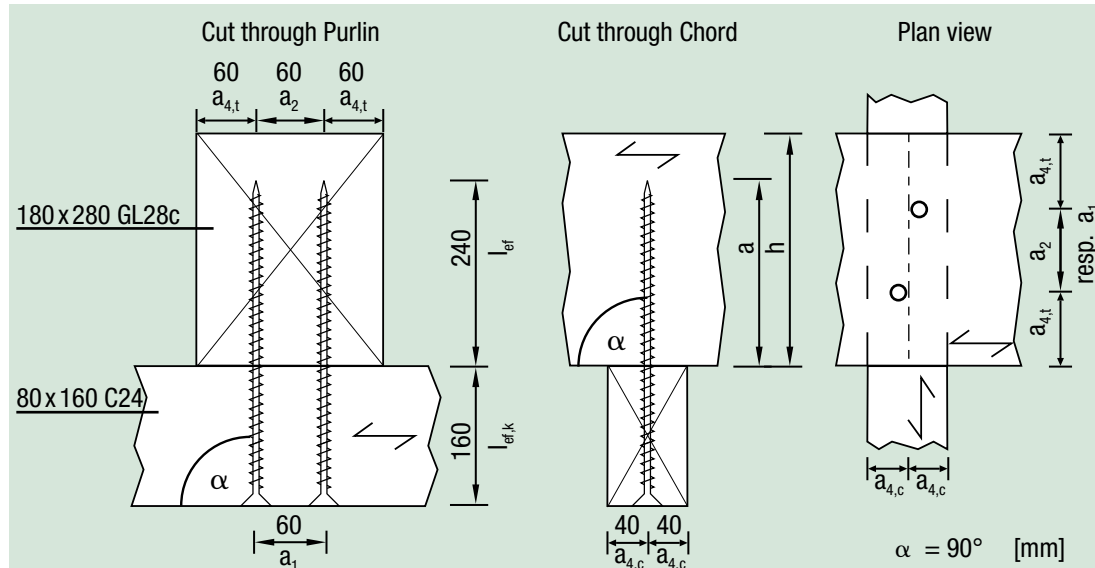
	A	B	C	D	E	F
1	Dimensions	6.0	8.0	10.0	12.0	Tolerance
2	Ø Da	18.0	25.0	32.0	40.0	± 0.3
3	Ø Di	6.5	8.5	11.0	13.0	
4	Ø D1	13.5	17.5	22.5	27.0	
5	Ø D2	12.5	16.5	21.5	26.0	
6	t	3.5	5.0	5.6	7.0	

ETA

9. Wood to wood Design example No 1

Connection of chord under a purlin with a full thread screw

Complementary information to this topic is available in the SPAX Timber Construction Report No 2



ETA

Service Cl. = 1, Load duration Cl. = Medium term $\rightarrow k_{mod} = 0.8$

(Tab. 4.3; F2+F5)

Selected fastener: SPAX 8.0x400 countersunk head, full thread with CUT point, per ETA-12/0114 w/o predrilling
Subject to (combined) shear and withdrawal

Minimum dimensions of members to prevent wood splitting

(Tab. 6.3 b; E)

SPAX screw with $d_1 = 8.0 \text{ mm}$: minimum section $A_{min} = 40 \cdot d_1^2 = 40 \cdot 8.0^2 = 2,560 \text{ mm}^2$

Chord: section $A = 80 \text{ mm} \cdot 160 \text{ mm} = 14,400 \text{ mm}^2 > 2,560 \text{ mm}^2 \rightarrow \text{satisfied}$

Purlin: section $A = 180 \text{ mm} \cdot 280 \text{ mm} = 54,000 \text{ mm}^2 > 2,560 \text{ mm}^2 \rightarrow \text{satisfied}$

Minimum thickness $t_{min} = 7 \cdot d_1 = 7 \cdot 8.0 \text{ mm} = 56 \text{ mm}$

(Tab. 6.3 b; E5)

Chord $t_{vorh} = 160 \text{ mm} > 56 \text{ mm} \rightarrow \text{satisfied}$

Purlin $t_{vorh} = 280 \text{ mm} > 56 \text{ mm} \rightarrow \text{satisfied}$

Minimum spacing, end and edge distances for combined shear and withdrawal

(Tab. 6.3 b; E)

$a_1 = 5 \cdot d_1 = 5 \cdot 8.0 \text{ mm} = 40 \text{ mm}$	set to $a_1 = 60 \text{ mm}$	$\rightarrow \text{satisfied}$
$a_2 = 3 \cdot d_1 = 3 \cdot 8.0 \text{ mm} = 24 \text{ mm}$	set to $a_2 = 60 \text{ mm}$	$\rightarrow \text{satisfied}$
$a_{3,t} \text{ and } a_{3,c} = 12 \cdot d_1 = 12 \cdot 8.0 \text{ mm} = 96 \text{ mm}$	actual $a_{3,c} > 96 \text{ mm}$	$\rightarrow \text{satisfied}$
$a_{4,t} = 7 \cdot d_1 = 7 \cdot 8.0 \text{ mm} = 56 \text{ mm}$	set to $a_{4,t} = 60 \text{ mm}$	$\rightarrow \text{satisfied}$
$a_{4,c} = 3 \cdot d_1 = 3 \cdot 8.0 \text{ mm} = 24 \text{ mm}$	set to $a_{4,c} = 40 \text{ mm}$	$\rightarrow \text{satisfied}$

Shear resistance – per fastener

1. Minimum required thickness resp. penetration depth t_{req} for multiple yield failure mode

$t_1 = 160 \text{ mm} > t_{1,req} = 50.5 \text{ mm} \rightarrow \text{satisfied}$

(Tab. 7.1; E5)

$t_2 = 240 \text{ mm} > t_{2,req} = 47.6 \text{ mm} \rightarrow \text{satisfied}$

(Tab. 7.1; F4)

\rightarrow No reduction of characteristic resistance $F_{v,Rk}$ necessary!

2. Characteristic resistance $F_{v,Rk}$

$F_{v,Rk} = 2,662 \text{ N}$

(Tab. 7.3; H5)

$\gamma_M = 1.3$

$F_{v,Rd} = \frac{0.8 \cdot 2,662 \text{ N}}{1.3} = 1,638 \text{ N}$

9. Wood to wood Design example No 1

Connection of chord under a purlin with a full thread screw

3. Possible increase ΔR_k due to contribution of the rope effect

$$\Delta R_k = \min \begin{cases} 2,662 \text{ N (governing)} \\ 0.25 \cdot 15,360 \text{ N} = 3,840 \text{ N} \end{cases} \quad (\text{see below})$$

$$F_{v,Rk} = 2,662 \text{ N} + 2,662 \text{ N} = 5,324 \text{ N}$$

$$\gamma_M = 1.3$$

$$F_{v,Rd} = \frac{0.8 \cdot 5,324 \text{ N}}{1.3} = \underline{\underline{3,276 \text{ N}}} \quad (100 \% \text{ increase})$$

4. Effective number of fasteners n_{ef}

For one row perpendicular to the grain direction of SPAX screws staggered by $1 \cdot d_1$, the effective number of fasteners is $n_{ef} = 2$.

(§5.1.3)

Withdrawal resistance – per fastener

1. Withdrawal of the threaded part

$$l_{ef} = 240 \text{ mm}$$

$$F_{ax,\alpha,Rk} = 102.5 \text{ N/mm} \cdot 240 \text{ mm} = 24,600 \text{ N}$$

(Tab. 7.14; H5)

$$\gamma_M = 1.3$$

$$F_{ax,\alpha,Rd} = \frac{0.8 \cdot 24,600 \text{ N}}{1.3} = 15,138 \text{ N}$$

2. Tensile steel resistance

$$f_{tens,k} = 17,000 \text{ N}$$

(Tab. 7.15; G3)

$$\gamma_M = 1.3$$

$$f_{tens,d} = \frac{17,000 \text{ N}}{1.3} = 13,077 \text{ N}$$

(Tab. 7.15; G4)

3. Head pull-through

$$F_{ax,\alpha,Rk} = \max \begin{cases} 3.1 \text{ Head pull-through} \\ 3.2 \text{ withdrawal of threaded part headside} \end{cases}$$

- 3.1 Head pull-through

$$F_{ax,\alpha,Rk} = 2,713 \text{ N}$$

(Tab. 7.16; G6)

$$\gamma_M = 1.3$$

$$F_{ax,\alpha,Rd} = \frac{0.8 \cdot 2,713 \text{ N}}{1.3} = 1,670 \text{ N}$$

- 3.2 Withdrawal of threaded part headside

$$l_{ef,k} = 160 \text{ mm}$$

$$F_{ax,\alpha,Rk} = 96.0 \text{ N/mm} \cdot 160 \text{ mm} = 15,360 \text{ N}$$

(Tab. 7.14; H4)

$$\gamma_M = 1.3$$

$$F_{ax,\alpha,Rd} = \frac{0.8 \cdot 15,360 \text{ N}}{1.3} = \underline{\underline{9,452 \text{ N}}} \quad (\text{governing})$$

Verification of wood members

As the ratio $a/h > 0.7$ ($l_{ef} = 240 \text{ mm} > t_2 \cdot 0.7 = 196 \text{ mm}$), verification of tension perpendicular to the grain stress induced by the fastener in member 2 is not necessary.

NA/A1; 8.1.4

Minimum spacing, end and edge distances for withdrawal only

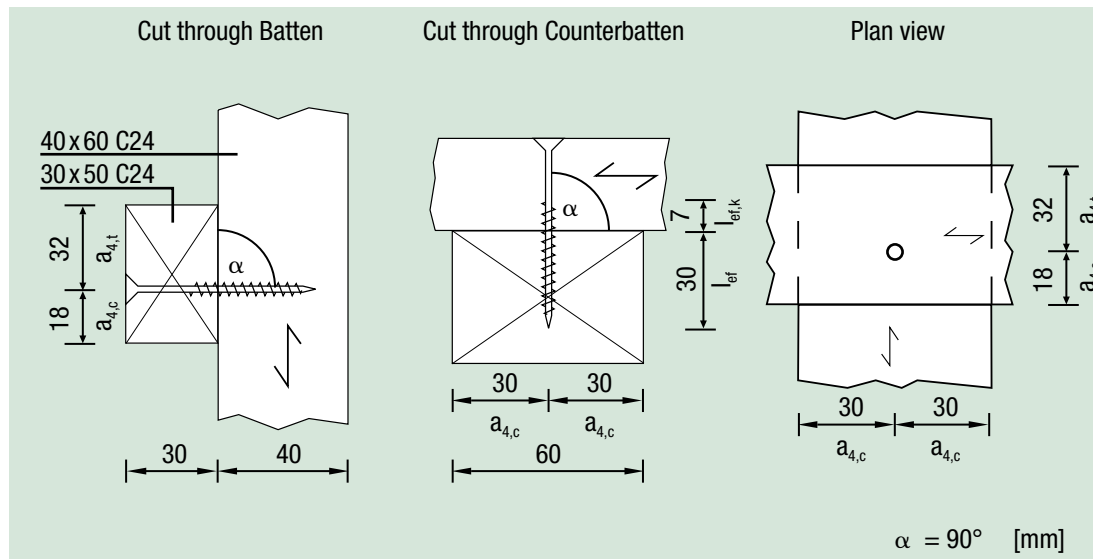
(Tab. 6.3 b; F)

If the SPAX screws were loaded in withdrawal only, the following minimum spacing, end and edge distances could be used:

$a_1 = 5 \cdot d_1 = 5 \cdot 8.0 \text{ mm} = 40 \text{ mm}$	set to $a_1 = 60 \text{ mm}$	-> satisfied
$a_2 = 5 \cdot d_1 = 5 \cdot 8.0 \text{ mm} = 40 \text{ mm}$	set to $a_2 = 60 \text{ mm}$	-> satisfied
$a_{3,c} = 5 \cdot d_1 = 5 \cdot 8.0 \text{ mm} = 40 \text{ mm}$	actual $a_{3,c} > 40 \text{ mm}$	-> satisfied
$a_{4,c} = 3 \cdot d_1 = 3 \cdot 8.0 \text{ mm} = 24 \text{ mm}$	set to $a_{4,c} = 40 \text{ mm}$	-> satisfied

9. Wood to wood Design example No 2

Connection of roof batten to a counterbatten



ETA

Service Cl. = 2, Load duration Cl. = short term $\rightarrow k_{mod} = 0.9$

(Tab. 4.3; G3)

Selected fastener: SPAX 4.5 x 60 countersunk head, partial thread with 4CUT point in stainless steel A2 per ETA-12/0114 w/o predrilling

Head diameter $d_k = 8.8$ mm

(Tab. 8.4 a; E5)

Length of partial thread $l_{gT} = 37$ mm

(Tab. 8.4 a; E15)

Subject to (combined) shear and withdrawal

Minimum dimensions of members to prevent wood splitting

(Tab. 6.3 b; C)

SPAX screw with $d_1 = 4.5$ mm: minimum section $A_{min} = 40 \cdot d_1^2 = 40 \cdot 4.5^2 \text{ mm}^2 = 810 \text{ mm}^2$

(Tab. 6.3 b; C3)

Batten: section $A = 50 \text{ mm} \cdot 30 \text{ mm} = 1,500 \text{ mm}^2 > 810 \text{ mm}^2 \rightarrow$ satisfied

Counterbatten: section $A = 40 \text{ mm} \cdot 60 \text{ mm} = 2,400 \text{ mm}^2 > 810 \text{ mm}^2 \rightarrow$ satisfied

Minimum thickness $t_{min} = 6 \cdot d_1 = 6 \cdot 4.5 \text{ mm} = 27 \text{ mm}$

(Tab. 6.3 b; C5)

Batten $t_{vorh} = 30 \text{ mm} > 27 \text{ mm} \rightarrow$ satisfied

Counterbatten $t_{vorh} = 40 \text{ mm} > 27 \text{ mm} \rightarrow$ satisfied

Minimum spacing, end and edge distances for combined shear and withdrawal

(Tab. 6.3 b; C)

$a_{4,t} = 7 \cdot d_1 = 7 \cdot 4.5 \text{ mm} = 31.5 \text{ mm}$ set to $a_{4,t} = 32 \text{ mm} \rightarrow$ satisfied

$a_{4,c} = 3 \cdot d_1 = 3 \cdot 4.5 \text{ mm} = 13.5 \text{ mm}$ set to $a_{4,c} = 18 \text{ mm} \rightarrow$ satisfied

Shear resistance – per fastener

1. Minimum required thickness resp. penetration depth t_{req} for multiple yield failure mode

$t_1 = 30 \text{ mm} > t_{1,req} = 30 \text{ mm} \cdot 0.839 = 25.2 \text{ mm} \rightarrow$ satisfied (Tab. 7.2; E4 · Tab. 7.2a; C3)

$t_2 = 60 \text{ mm} - 30 \text{ mm} = 30 \text{ mm} > t_{2,req} = 30 \text{ mm} \cdot 0.839 = 25.2 \text{ mm} \rightarrow$ satisfied (Tab. 7.2; E4 · Tab. 7.2a; C3)

\rightarrow No reduction of characteristic resistance $F_{v,Rk}$ necessary!

2. Characteristic resistance $F_{v,Rk}$

$F_{v,Rk} = 989 \text{ N} \cdot 0.816 = 807 \text{ N}$

(Tab. 7.3; E4 · Tab. 7.3a; C3)

$\gamma_M = 1.3$

$F_{v,Rd} = \frac{0.9 \cdot 807 \text{ N}}{1.3} = 559 \text{ N}$

9. Wood to wood Design example No 2

Connection of roof batten to a counterbatten

3. Possible increase ΔR_k due to contribution of the rope effect

$$\Delta R_k = \min \begin{cases} 807 \text{ N} \\ 0.25 \cdot 1,409 \text{ N} = 352 \text{ N (governing) (see below)} \end{cases} \quad (\text{Tab. 7.3b; D5})$$

$$\begin{aligned} F_{v,Rk} &= 807 \text{ N} + 352 \text{ N} = 1,159 \text{ N} \\ \gamma_M &= 1.3 \\ F_{v,Rd} &= \frac{0.9 \cdot 1,159 \text{ N}}{1.3} = \underline{\underline{802 \text{ N}}} \quad (44 \% \text{ increase}) \end{aligned}$$

Withdrawal resistance – per fastener

1. Withdrawal of the threaded part

$$\begin{aligned} l_{ef} &= \min \begin{cases} t_2 = 30 \text{ mm (governing)} \\ l_{gT} = 37 \text{ mm} \end{cases} \\ F_{ax,\alpha,Rk} &= 63.0 \text{ N/mm} \cdot 30 \text{ mm} = 1,890 \text{ N} \quad (\text{Tab. 7.14; E4}) \\ \gamma_M &= 1.3 \\ F_{ax,\alpha,Rd} &= \frac{0.9 \cdot 1,890 \text{ N}}{1.3} = 1,308 \text{ N} \end{aligned}$$

2. Tensile steel resistance

$$\begin{aligned} f_{tens,k} &= 4,200 \text{ N} \quad (\text{Tab. 7.15; D5}) \\ \gamma_M &= 1.3 \\ f_{tens,d} &= \frac{4,200 \text{ N}}{1.3} = 3,231 \text{ N} \quad (\text{Tab. 7.15; D6}) \end{aligned}$$

3. Head pull-through

$$F_{ax,\alpha,Rk} = \max \begin{cases} 3.1 \text{ head pull-through} \\ 3.2 \text{ withdrawal of threaded part headside} \end{cases}$$

- 3.1 Head pull-through

$$\begin{aligned} F_{ax,\alpha,Rk} &= 1,409 \text{ N} \quad (\text{Tab. 7.16; D6}) \\ \gamma_M &= 1.3 \\ F_{ax,\alpha,Rd} &= \frac{0.9 \cdot 1,409 \text{ N}}{1.3} = \underline{\underline{975 \text{ N}}} \quad (\text{governing}) \end{aligned}$$

- 3.2 Withdrawal of threaded part headside

$$\begin{aligned} l_{ef,k} &= 37 \text{ mm} - 30 \text{ mm} = 7 \text{ mm} \\ F_{ax,\alpha,Rk} &= 63.0 \text{ N/mm} \cdot 7 \text{ mm} = 441 \text{ N} \quad (\text{Tab. 7.14; E4}) \\ \gamma_M &= 1.3 \\ F_{ax,\alpha,Rd} &= \frac{0.9 \cdot 441 \text{ N}}{1.3} = 305 \text{ N} \end{aligned}$$

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