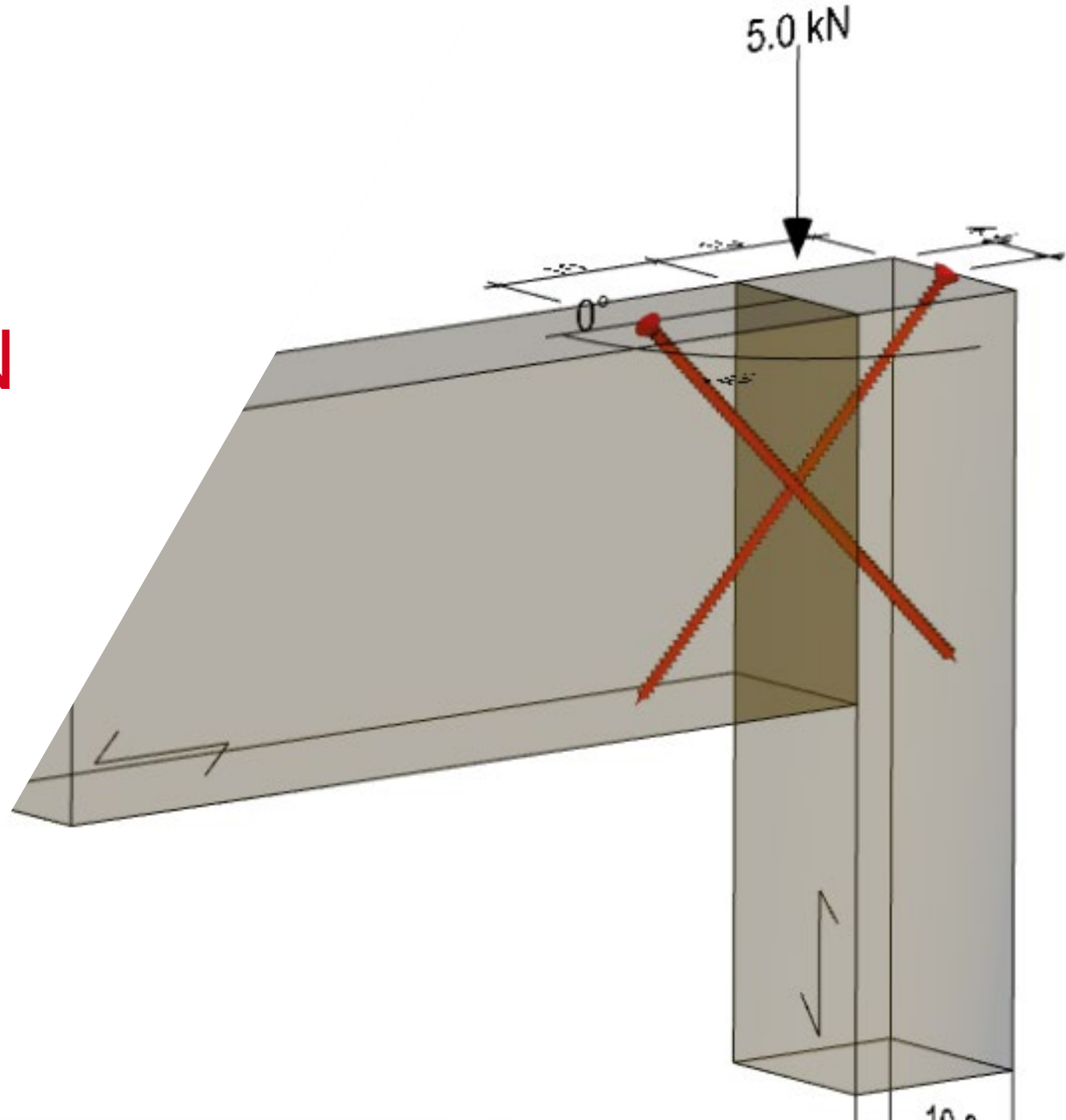




REKENEN IN HOUTVERBINDINGEN

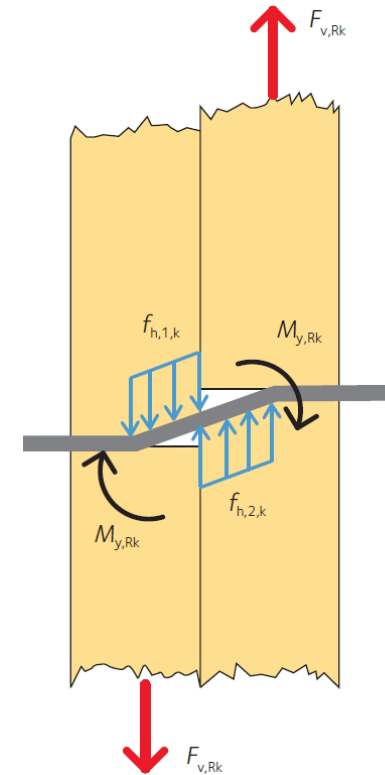


Rekenen in houtverbindingen



AGENDA

1. Rekenen met schroeven
2. Mogelijkheden software
3. Jullie vragen



REKENEN MET SCHROEVEN

WELKE SCHROEVEN ZIJN ER?



Posistie:

1

2

3

4

5

REKENWAARDEN BEPALEN

Twee dingen belangrijk:

1. Tijdsduur van de belasting (k_{mod})

Hoe korter de belasting, hoe kleiner de vermindering van capaciteit

2. Factoren afhankelijk van de toepassing, bij verbindingen altijd **1,3**

$$F_{Rd} = \frac{F_{Rk} \cdot k_{mod}}{\gamma_M}$$

SCHROEVEN IN EEN CONSTRUCTIE

1. Schroeven op trek
2. Schroeven op afschuif



Afschuif toetsing (hout/hout)

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

trek toetsing

$$F_{ax,\alpha,Rk} = \frac{n_{ef} f_{ax,k} d \ell_{ef}}{1,2 \cos^2 \alpha + \sin^2 \alpha} \left(\frac{\rho_k}{\rho_a} \right)^{0,8}$$

$$F_{t,Rk} = n_{ef} f_{tens,k}$$

$$F_{ax,\alpha,Rk} = n_{ef} f_{head,k} d_h^2 \left(\frac{\rho_k}{\rho_a} \right)^{0,8}$$

SCHROEVEN OP AFSCHUIF BELASTEN

De diameter van de schroef...bepaalt of je rekent als een nagel of als een stift/bout

(4) For smooth shank screws with a diameter $d > 6$ mm, the rules in 8.5.1 apply.



(5) For smooth shank screws with a diameter of 6 mm or less, the rules of 8.3.1 apply.



$$f_{h,\alpha,k} = \frac{f_{h,0,k}}{k_{90} \sin^2 \alpha + \cos^2 \alpha}$$

$$f_{h,0,k} = 0,082 (1 - 0,01 d) \rho_k$$

Wél invloed van hoek van belasting



- without predrilled holes

$$f_{h,k} = 0,082 \rho_k d^{-0,3} \quad \text{N/mm}^2$$

- with predrilled holes

$$f_{h,k} = 0,082 (1 - 0,01 d) \rho_k \quad \text{N/mm}^2$$

Geen invloed van hoek van belasting



SCHROEVEN OP AFSCHUIF BELASTEN



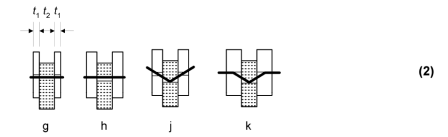
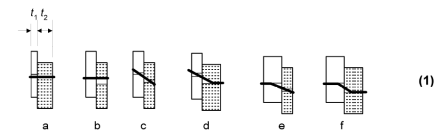
Bezwijkmechanismen

stuiken van hout

vervormen van hout

combinatie van beide

BEZWIJKMECHANISMEN



$$F_{V,Rk} = \min \left\{ \begin{array}{l} f_{h,1,k} t_1 d \quad (a) \\ f_{h,2,k} t_2 d \quad (b) \\ \frac{f_{h,1,k} t_1 d}{1+\beta} \left[\sqrt{\beta - 2\beta^2 \left[1 + \frac{t_2}{t_1} + \left(\frac{t_2}{t_1} \right)^2 \right] + \beta^3 \left(\frac{t_2}{t_1} \right)^2} - \beta \left(1 + \frac{t_2}{t_1} \right) \right] + \frac{F_{ax,Rk}}{4} \quad (c) \\ 1,05 \frac{f_{h,1,k} t_1 d}{2+\beta} \left[\sqrt{2\beta(1+\beta) + \frac{4\beta(2+\beta)M_{y,Rk}}{f_{h,1,k} d t_1^2}} - \beta \right] + \frac{F_{ax,Rk}}{4} \quad (d) \\ 1,05 \frac{f_{h,1,k} t_2 d}{1+2\beta} \left[\sqrt{2\beta^2(1+\beta) + \frac{4\beta(1+2\beta)M_{y,Rk}}{f_{h,1,k} d t_2^2}} - \beta \right] + \frac{F_{ax,Rk}}{4} \quad (e) \\ 1,15 \sqrt{\frac{2\beta}{1+\beta}} \sqrt{2M_{y,Rk} f_{h,1,k} d} + \frac{F_{ax,Rk}}{4} \quad (f) \end{array} \right.$$

FACTOREN IN FORMULES

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

Dit is de verhouding tussen de stuksterkte van de twee verschillende materialen in de verbinding

$$M_{y,Rk}$$

Dit is de elastisch/plastische werking van het anker

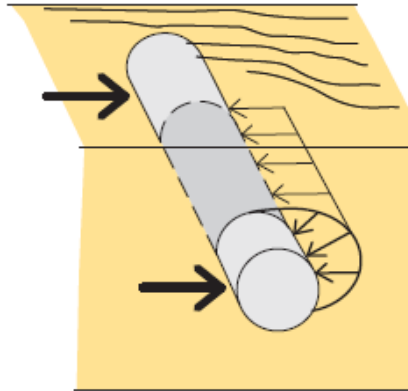
$$f_{h,i,k}$$

Dit is de stuksterkte van het bevestigingsmiddel in het hout.

$$1,05 \frac{f_{h,1,k} t_2 d}{1+2\beta} \left[\sqrt{2\beta^2(1+\beta) + \frac{4\beta(1+2\beta)M_{y,Rk}}{f_{h,1,k} d t_2^2}} - \beta \right] + \frac{F_{ax,Rk}}{4}$$

INDRUKKEN VAN HOUT

$f_{h,i,k}$



Dit is de **stuiksterkte** van het bevestigingsmiddel in het hout.

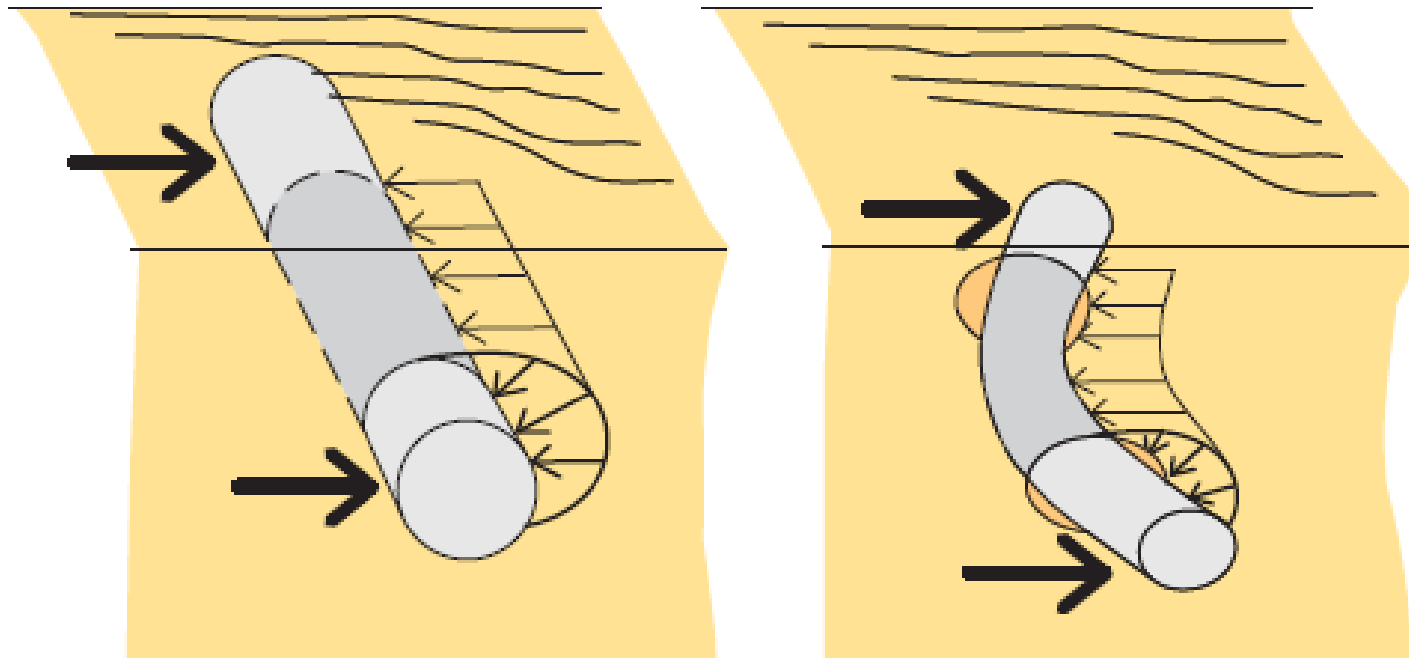
Hoe makkelijk druk je het hout in?

Uitgedrukt in N/mm²

(o.a. afhankelijk van type hout, verbindingmiddel en voorboren)

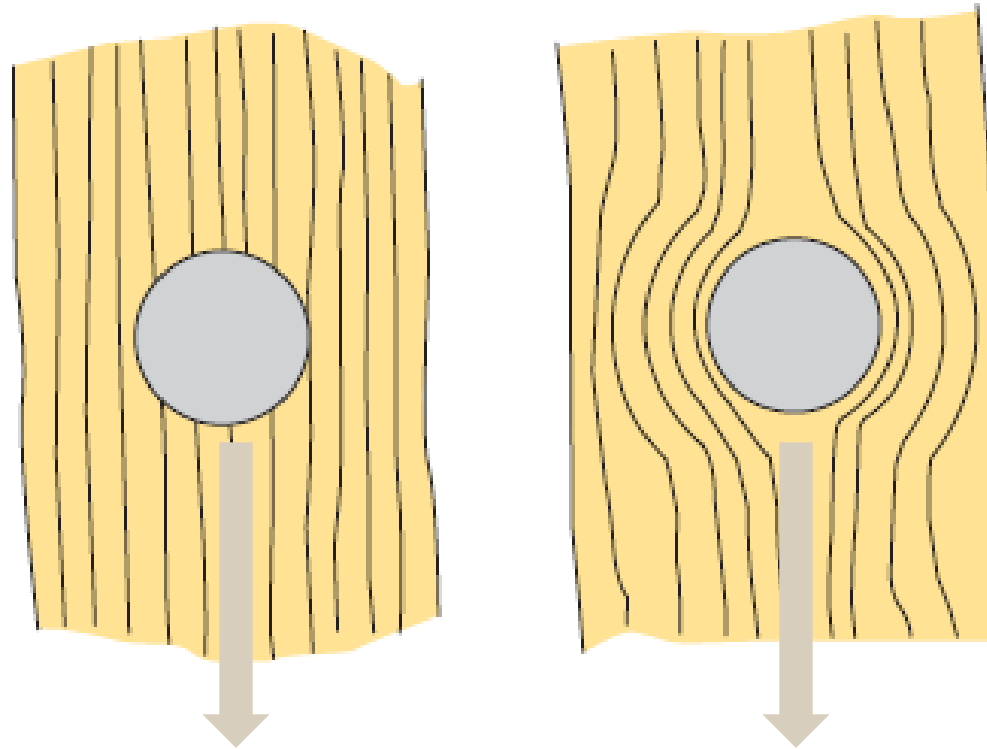
Picture source: Design of timber structures, vol 1, Swedish Wood

STUIKEN HOUT



Picture source: Design of timber structures, vol 1, Swedish Wood

BEZWIJKMECHANISMEN AFSCHUIF



Picture source: Design of timber structures, vol 1, Swedish Wood

VOORBEELD STUIKSTERKTE



Houtschroef S-WCP-S-8x140/80

Niet voorboren

Shear load bearing capacity per fastener and shear plane

component		1	2	
penetration depth	t_i	100	40	mm
Angle fastener axis - grain direction	α_i	90,0	90,0	°
Density	$\rho_{k,i}$	350	350	kg/m ³
Characteristic embedment strength	$f_{h,k,i}$	15,4	15,4	N/mm ²

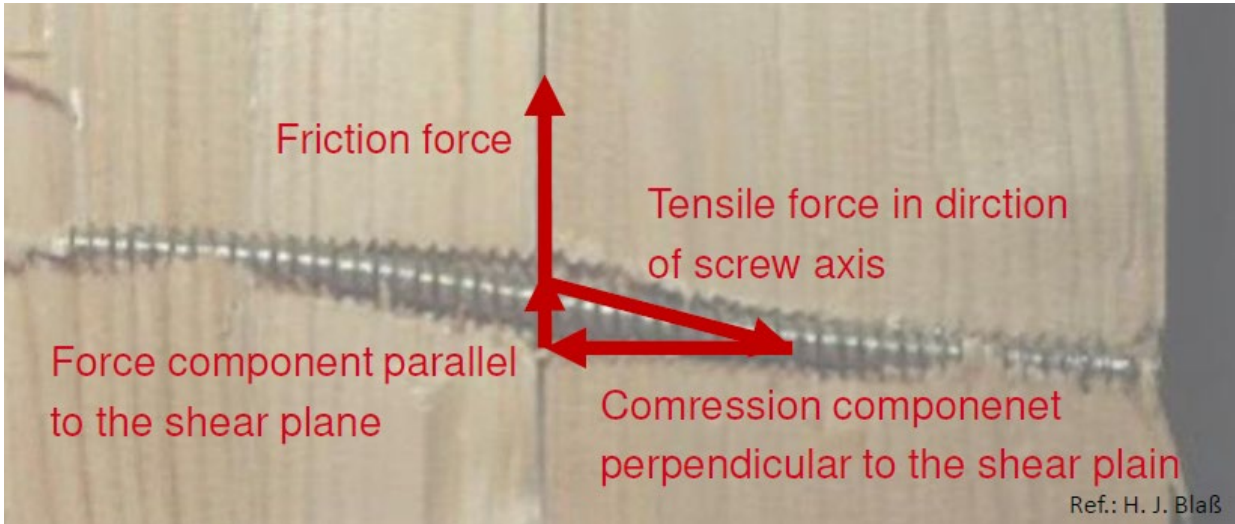
Wél voorboren

Shear load bearing capacity per fastener and shear plane

component		1	2	
penetration depth	t_i	100	40	mm
Angle fastener axis - grain direction	α_i	90,0	90,0	°
Density	$\rho_{k,i}$	350	350	kg/m ³
Characteristic embedment strength	$f_{h,k,i}$	26,4	26,4	N/mm ²

HET 'ROPE EFFECT' KABELEFFECT...

$$\frac{F_{ax,Rk}}{4}$$



INVLOED VAN ONDERLINGE AFSTANDEN (AFSCHUIF)

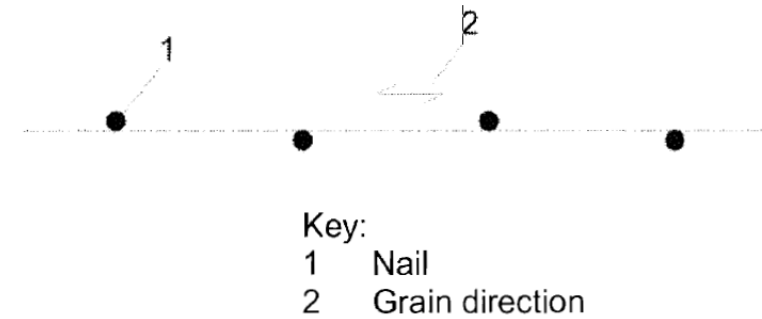
1. Eerst wordt de capaciteit van 1 schroef berekend
2. Dan wordt gekeken hoeveel schroeven in een rij 'effectief' meewerken

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

Table 8.1 – Values of k_{ef}

Spacing ^a	k_{ef}	
	Not predrilled	Predrilled
$a_1 \geq 14d$	1,0	1,0
$a_1 = 10d$	0,85	0,85
$a_1 = 7d$	0,7	0,7
$a_1 = 4d$	-	0,5

^a For intermediate spacings, linear interpolation of k_{ef} is permitted



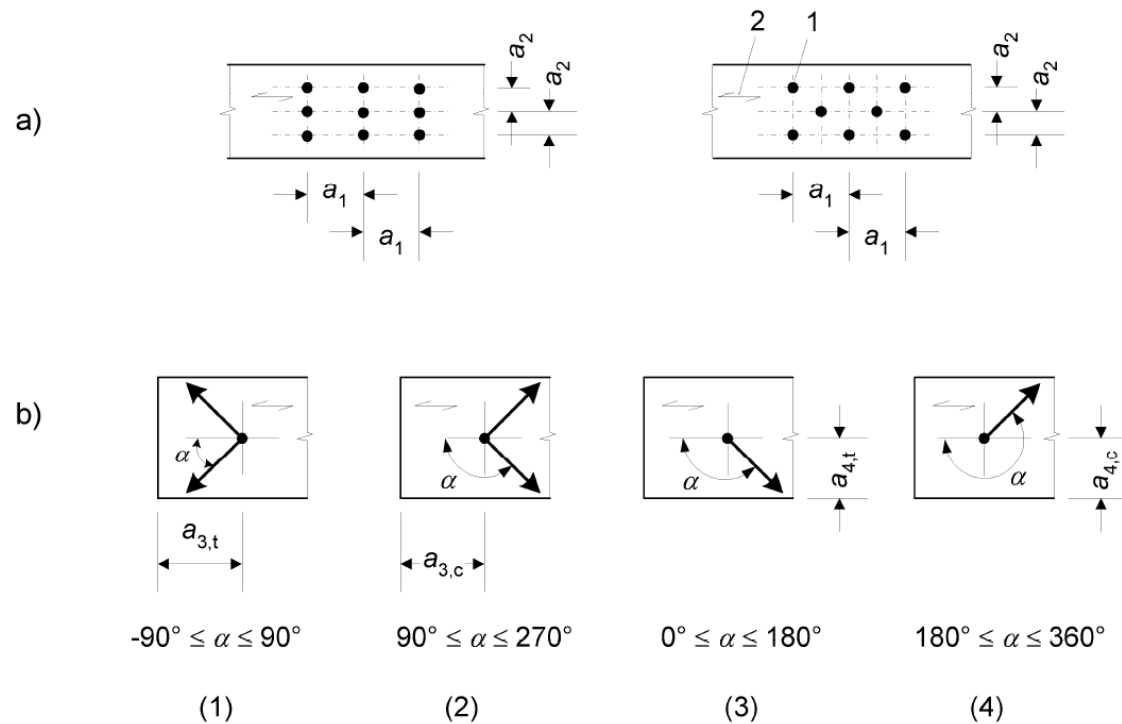
De onderlinge afstand tussen de schroeven in richting van de kracht en vezel bepalen voor een groot deel de capaciteit

INVLOED VAN ONDERLINGE AFSTANDEN (AFSCHUIF)

1. Eerst wordt dus de capaciteit van 1 schroef berekend
2. Dan wordt gekeken hoeveel schroeven in een rij 'effectief' meewerken
3. Vervolgens de minimale onderlinge afstanden e.d. bepaald

Table 8.2 – Minimum spacings and edge and end distances for nails

Spacing or distance (see Figure 8.7)	Angle α	Minimum spacing or end/edge distance		
		without predrilled holes		with predrilled holes
		$\rho_k \leq 420 \text{ kg/m}^3$	$420 \text{ kg/m}^3 < \rho_k \leq 500 \text{ kg/m}^3$	
Spacing a_1 (parallel to grain)	$0^\circ \leq \alpha \leq 360^\circ$	$d < 5 \text{ mm}$: $(5+5 \cos \alpha) d$ $d \geq 5 \text{ mm}$: $(5+7 \cos \alpha) d$	$(7+8 \cos \alpha) d$	$(4+ \cos \alpha) d$
Spacing a_2 (perpendicular to grain)	$0^\circ \leq \alpha \leq 360^\circ$	$5d$	$7d$	$(3+ \sin \alpha) d$
Distance $a_{3,t}$ (loaded end)	$-90^\circ \leq \alpha \leq 90^\circ$	$(10+5 \cos \alpha) d$	$(15+5 \cos \alpha) d$	$(7+5 \cos \alpha) d$
Distance $a_{3,c}$ (unloaded end)	$90^\circ \leq \alpha \leq 270^\circ$	$10d$	$15d$	$7d$
Distance $a_{4,t}$ (loaded edge)	$0^\circ \leq \alpha \leq 180^\circ$	$d < 5 \text{ mm}$: $(5+2 \sin \alpha) d$ $d \geq 5 \text{ mm}$: $(5+5 \sin \alpha) d$	$d < 5 \text{ mm}$: $(7+2 \sin \alpha) d$ $d \geq 5 \text{ mm}$: $(7+5 \sin \alpha) d$	$d < 5 \text{ mm}$: $(3+2 \sin \alpha) d$ $d \geq 5 \text{ mm}$: $(3+4 \sin \alpha) d$
Distance $a_{4,c}$ (unloaded edge)	$180^\circ \leq \alpha \leq 360^\circ$	$5d$	$7d$	$3d$



INVLOED VAN ONDERLINGE AFSTANDEN

Verschil tussen diameter schroeven!



tot 6mm



groter dan 6mm

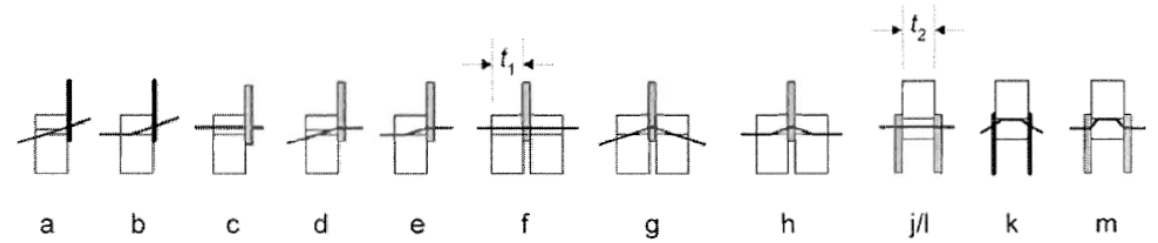
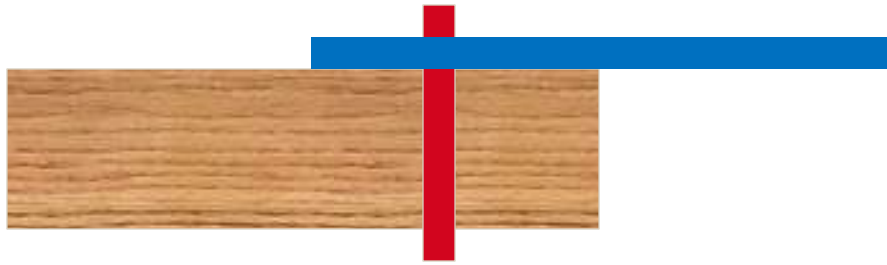
Table 8.2 – Minimum spacings and edge and end distances for nails

Spacing or distance (see Figure 8.7)	Angle α	Minimum spacing or end/edge distance		
		without predrilled holes		with predrilled holes
		$\rho_k \leq 420 \text{ kg/m}^3$	$420 \text{ kg/m}^3 < \rho_k \leq 500 \text{ kg/m}^3$	
Spacing a_1 (parallel to grain)	$0^\circ \leq \alpha \leq 360^\circ$	$d < 5 \text{ mm}$: $(5+5 \cos \alpha) d$ $d \geq 5 \text{ mm}$: $(5+7 \cos \alpha) d$	$(7+8 \cos \alpha) d$	$(4+ \cos \alpha) d$
Spacing a_2 (perpendicular to grain)	$0^\circ \leq \alpha \leq 360^\circ$	$5d$	$7d$	$(3+ \sin \alpha) d$
Distance $a_{3,t}$ (loaded end)	$-90^\circ \leq \alpha \leq 90^\circ$	$(10+5 \cos \alpha) d$	$(15+5 \cos \alpha) d$	$(7+5 \cos \alpha) d$
Distance $a_{3,c}$ (unloaded end)	$90^\circ \leq \alpha \leq 270^\circ$	$10d$	$15d$	$7d$
Distance $a_{4,t}$ (loaded edge)	$0^\circ \leq \alpha \leq 180^\circ$	$d < 5 \text{ mm}$: $(5+2 \sin \alpha) d$ $d \geq 5 \text{ mm}$: $(5+5 \sin \alpha) d$	$d < 5 \text{ mm}$: $(7+2 \sin \alpha) d$ $d \geq 5 \text{ mm}$: $(7+5 \sin \alpha) d$	$d < 5 \text{ mm}$: $(3+2 \sin \alpha) d$ $d \geq 5 \text{ mm}$: $(3+4 \sin \alpha) d$
Distance $a_{4,c}$ (unloaded edge)	$180^\circ \leq \alpha \leq 360^\circ$	$5d$	$7d$	$3d$

Table 8.4 – Minimum values of spacing and edge and end distances for bolts

Spacing and end/edge distances (see Figure 8.7)	Angle	Minimum spacing or distance
a_1 (parallel to grain)	$0^\circ \leq \alpha \leq 360^\circ$	$(4 + \cos \alpha) d$
a_2 (perpendicular to grain)	$0^\circ \leq \alpha \leq 360^\circ$	$4 d$
$a_{3,t}$ (loaded end)	$-90^\circ \leq \alpha \leq 90^\circ$	$\max(7 d; 80 \text{ mm})$
$a_{3,c}$ (unloaded end)	$90^\circ \leq \alpha < 150^\circ$ $150^\circ \leq \alpha < 210^\circ$ $210^\circ \leq \alpha \leq 270^\circ$	$\max[(1 + 6 \sin \alpha) d; 4d]$ $4 d$ $\max[(1 + 6 \sin \alpha) d; 4d]$
$a_{4,t}$ (loaded edge)	$0^\circ \leq \alpha \leq 180^\circ$	$\max[(2 + 2 \sin \alpha) d; 3d]$
$a_{4,c}$ (unloaded edge)	$180^\circ \leq \alpha \leq 360^\circ$	$3 d$

AFSCHUIF STAAL-HOUT



$$F_{v,Rk} = \min \begin{cases} 0,4 f_{h,k} t_1 d & \text{(a)} \\ 1,15 \sqrt{2 M_{y,Rk} f_{h,k} d} + \frac{F_{ax,Rk}}{4} & \text{(b)} \end{cases}$$

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

verschil tussen **dunne** of **dikke** plaat

type schroef, plaatdikte, en ruimte om anker bepalend



SCHROEVEN OP TREK BELASTEN



Bezwijkmechanismen

Uittrekken van de schroef

Bezwijken schroef zelf

Doortrekken schroef

BEZWIJKMECHANISMEN

$$F_{ax,\alpha,Rk} = \frac{n_{ef} f_{ax,k} d l_{ef}}{1,2 \cos^2 \alpha + \sin^2 \alpha} \left(\frac{\rho_k}{\rho_a} \right)^{0,8}$$



$$F_{t,Rk} = n_{ef} f_{tens,k}$$



$$F_{ax,\alpha,Rk} = n_{ef} f_{head,k} d_h^2 \left(\frac{\rho_k}{\rho_a} \right)^{0,8}$$

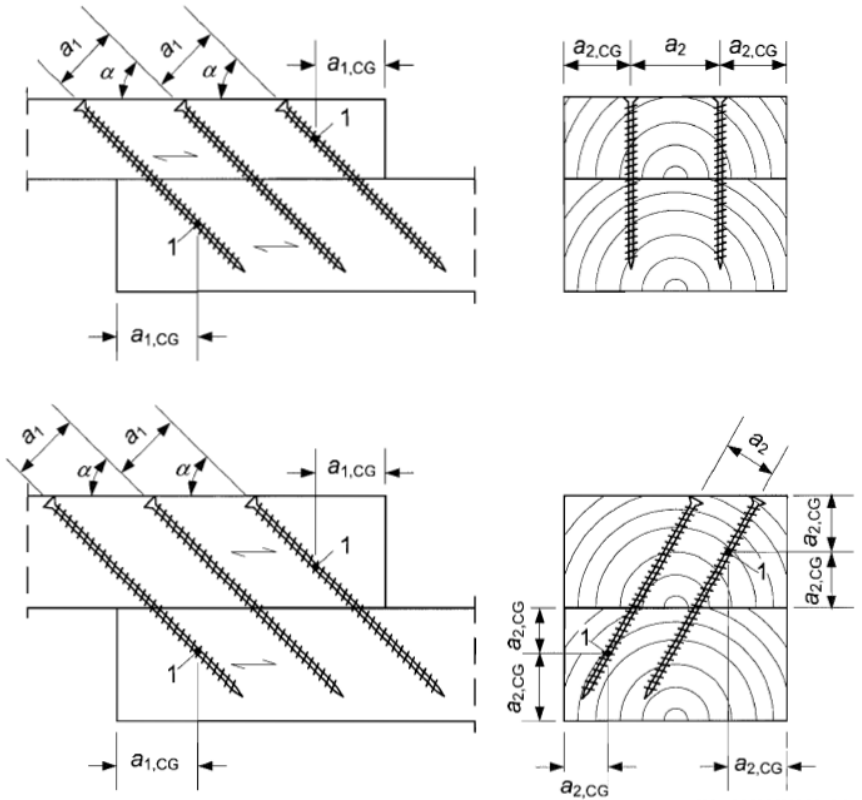


$$n_{ef} = n^{0,9}$$

INVLOED VAN ONDERLINGE AFSTANDEN (TREK)

Table 8.6 – Minimum spacings and end and edge distances for axially loaded screws

Minimum screw spacing in a plane parallel to the grain	Minimum screw spacing perpendicular to a plane parallel to the grain	Minimum end distance of the centre of gravity of the threaded part of the screw in the member	Minimum edge distance of the centre of gravity of the threaded part of the screw in the member
a_1	a_2	$a_{1,CG}$	$a_{2,CG}$
$7d$	$5d$	$10d$	$4d$

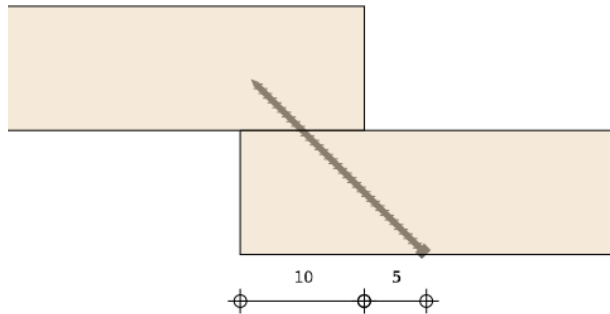


AFSCHUIFKRACHTEN ALS TREKBELASTING OPNEMEN



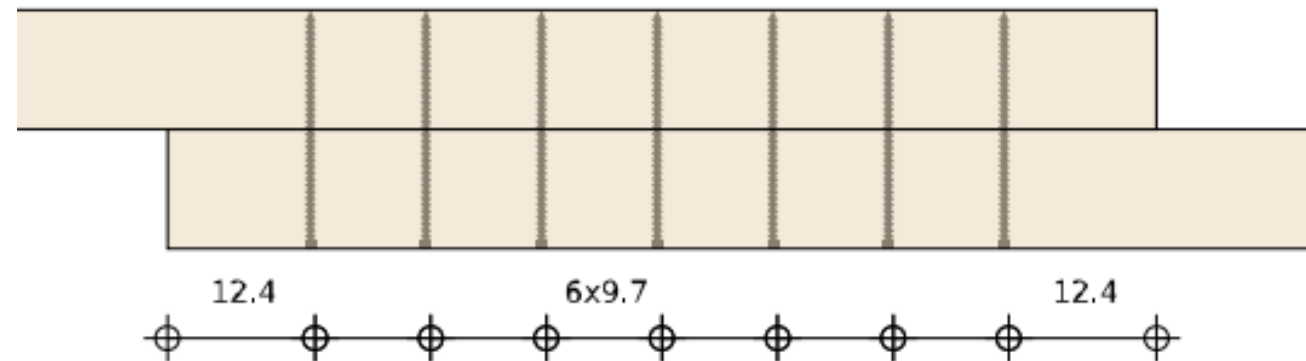
Schroeven schuin...

6 schroeven 200 lang, **weinig** overlapping



Schroeven recht...

7 schroeven 200 lang, **veel** overlapping



GEBRUIK DE SOFTWARE!



Insulation of roof/façade



Axial and shear connection



Connection of main and secondary beams



Tension shear connection



Notch



Opening



Transverse connection



Transverse pressure verification and transverse pressure reinforcement



Duplication of beams



Lateral reinforcement of beams

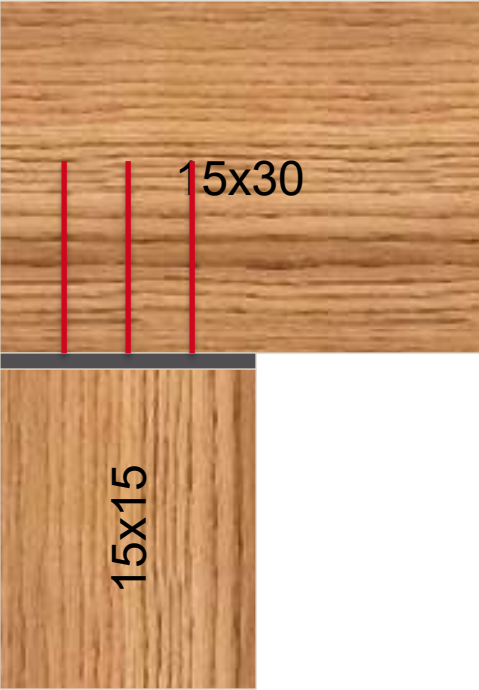


Beam head refurbishment

START

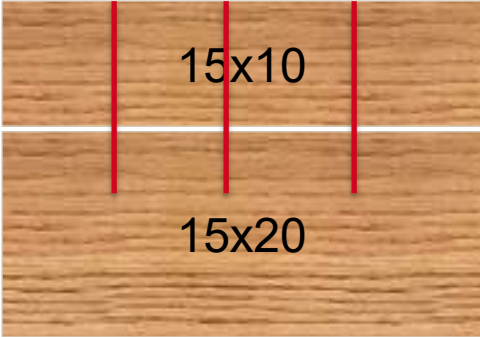
'TRUCJES' MET SCHROEVEN

Druk verdelen over vezels



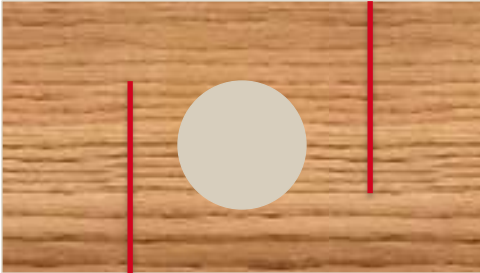
50 kN

Balklagen versterken



Overspanning 4 meter
2 kNm

Balk 'wapenen' bij opening of oplegging



BEDANKT VOOR UW AANDACHT!

HILTI ASK HILTI

<https://ask.hilti.nl/>



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