Consequences of EC 5 for Danish best practise

Jørgen Munch-Andersen
Danish Timber Information

Introduction 1

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- Eurocodes replaces Danish Codes from 1 Jan 2009
- Most strength parameters should be declared in the CE-mark in accordance with prEN14592
- Eurocode 5 equations can be used where applicable, but Initial Type Testing (ITT) is needed for many types of fasteners
- Eurocode 5 ought to give slightly conservative parameters

Introduction 2

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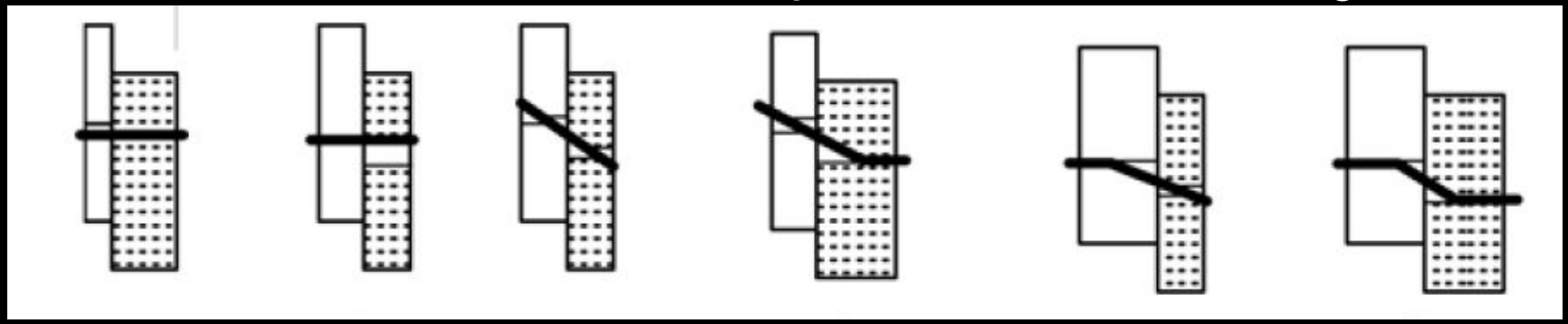
- Load capacity for fasteners generally decreases
- Some common Danish connection types can no longer be used

Strength parameters

Dowel ($F_{Johansen}$): combination of

- Embedment strength of timber – depends on density
- Yield moment of dowel – depends on steel strength



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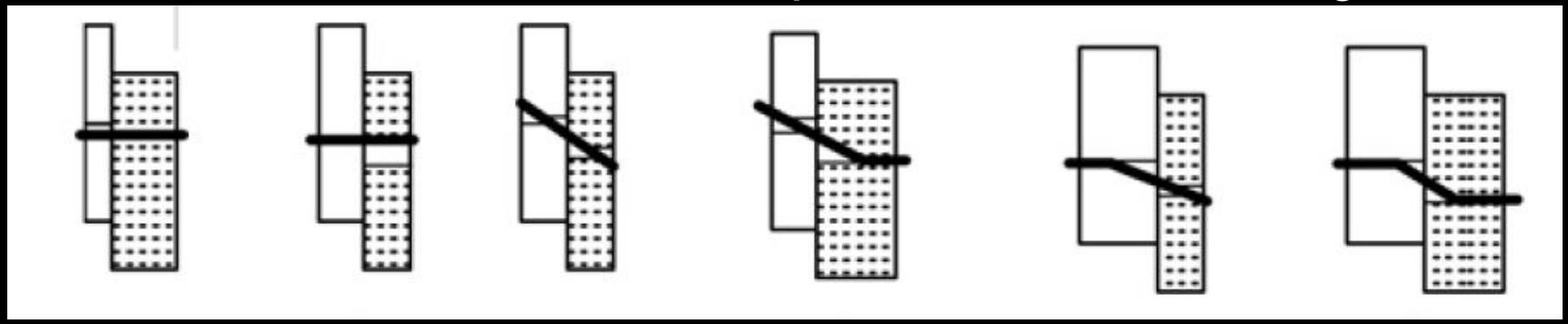

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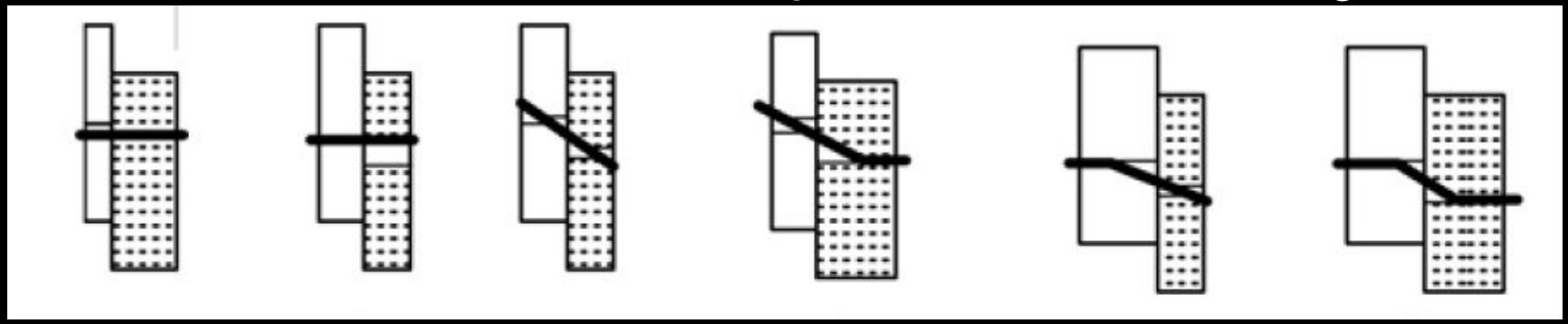

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Lateral load

- Combination of dowel and tension
- Eurocode: $F_v = F_{Johansen} + F_{ax}/4$

Density 1

- Well established that strength of fasteners depend on timber density
- Characteristic densities in EN 338 decrease rapidly with decreasing strength class:

C30	C24	C18	C14
380 kg/m^3	350 kg/m^3	320 kg/m^3	290 kg/m^3

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- Densities below 350 kg/m^3 very hard to find
- Up to now 350 kg/m^3 has been presupposed for all strength classes in Denmark
- C18 is most widely uses in Denmark – looses 10 % of density

Density 2

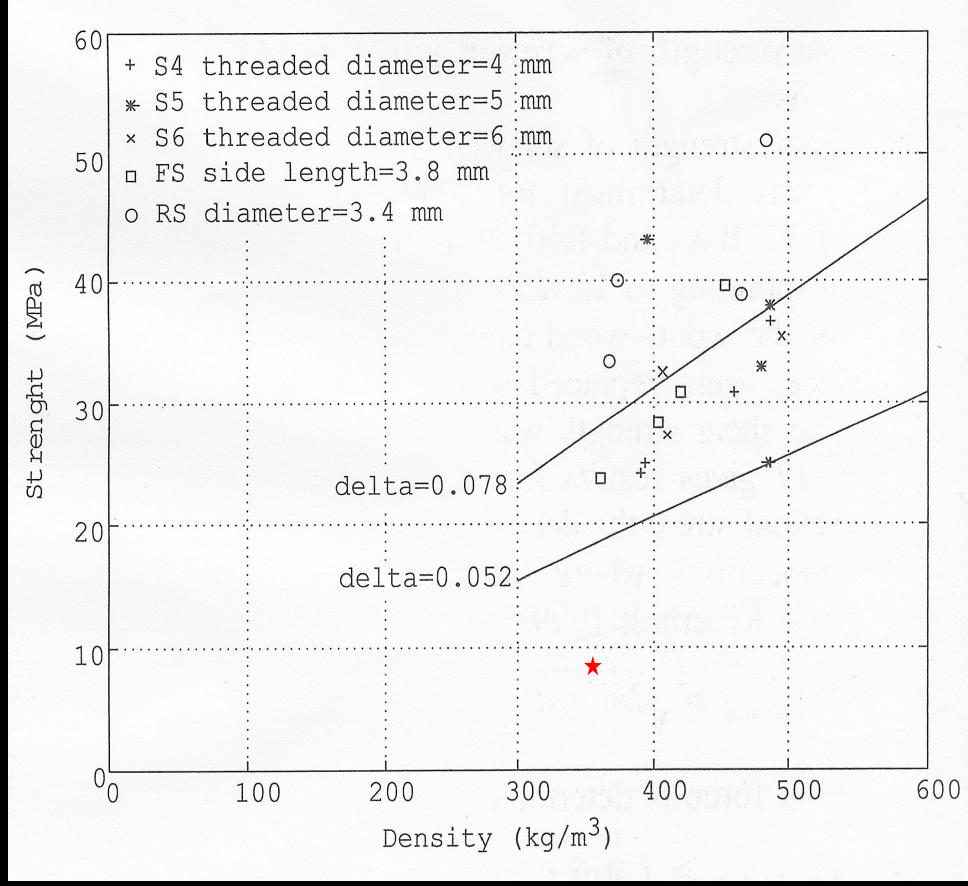
- Strength class for Nordic timber is usually governed by knot sizes – not the clear wood properties
- This might explain why the experience using 350 kg/m^3 is good
- If different grow conditions causes other relations for timber grown in other places EN 338 ought to take account of regional differences

Axially loaded fasteners

- Head pull-through
- Withdrawal

Head pull-through

- Eurocode value formally given only for smooth nails
- Very low strength given



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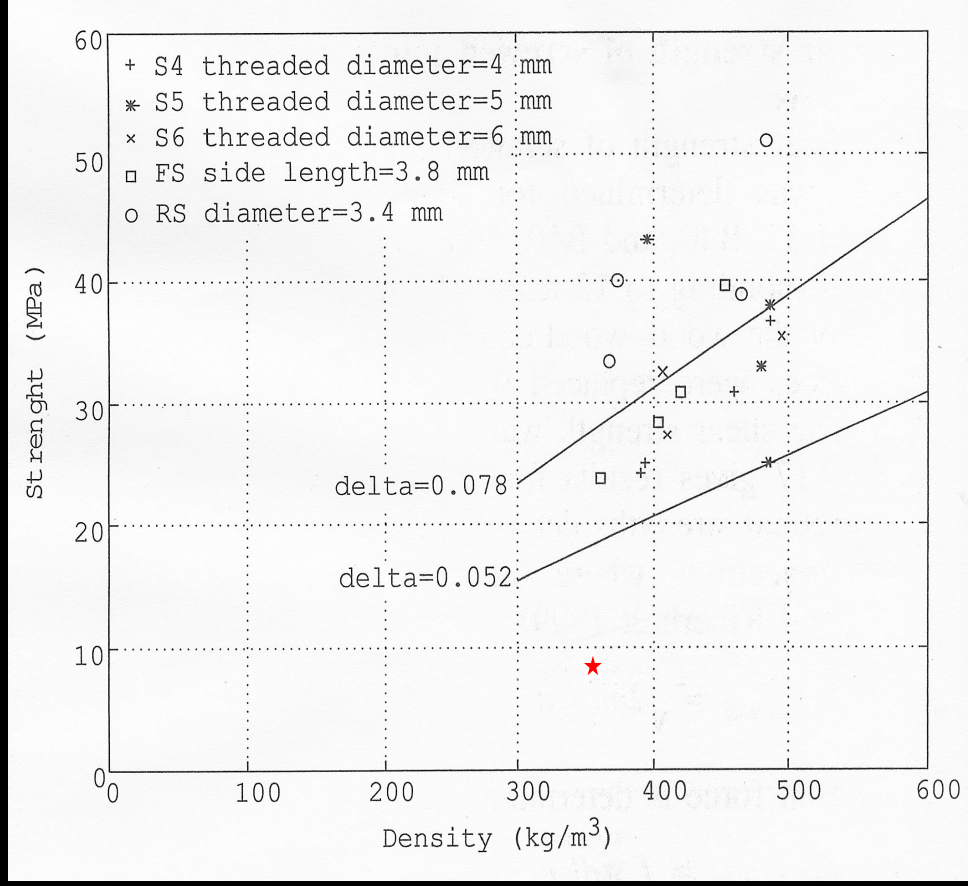
- Should be similar for threaded nails and screws
- Nails: Depends on ρ^2 !
- Screws: Depends on $\rho^{0.8}$?
- A linear relationship appears reasonable for test values



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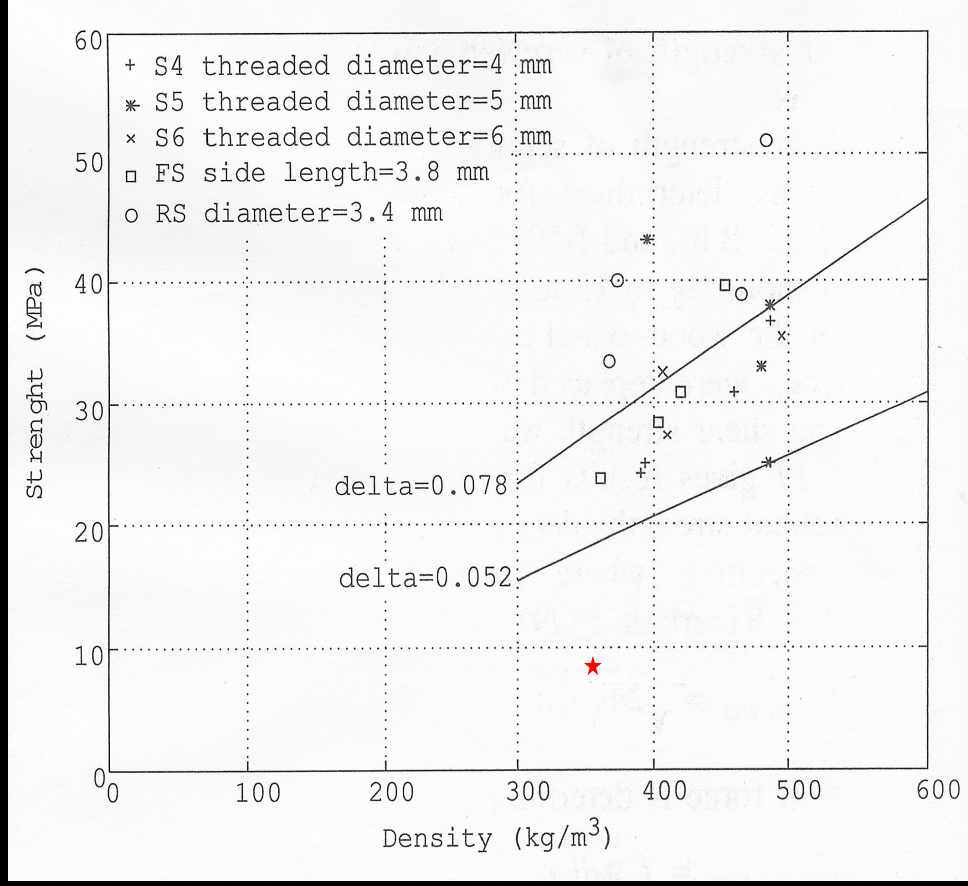

- A linear relationship appears reasonable for test values
- Correction from $\rho = 350$ to $\rho = 410$ with $\rho^{0.8}$ makes only 3% difference form linear correction !

Correction of measured strength for density

Example:

Head pull through, threaded nail, d_{head} = 5.5 mm

- F_{mean} = 1500 N, CoV = 12.5%, ρ = 475 kg/m^3
- $f_{k,475}$ ~ 0.75 ·1500/5.5^2 = 36,4 MPa
- Approved institute corrects to ρ = 350 kg/m^3 assuming linear relationship:
  $f_{k,350}$ = 26.8 MPa (~ 3 x EC5 for smooth nail)
- Using EC5's ρ^2-dependency unsafe for high ρ
- Correction must be done with ρ^2:
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- Preferable to use timber with smaller density for tests – or a range of densities including low densities

Withdrawal – smooth nails

- Strength parameters given are NOT conservative!
  – especially not for round nails
- No difference in EC5 between round and square nails
- Reduction factor 2/3 for timber near to saturation not enough according to old Danish tests, might be 1/3

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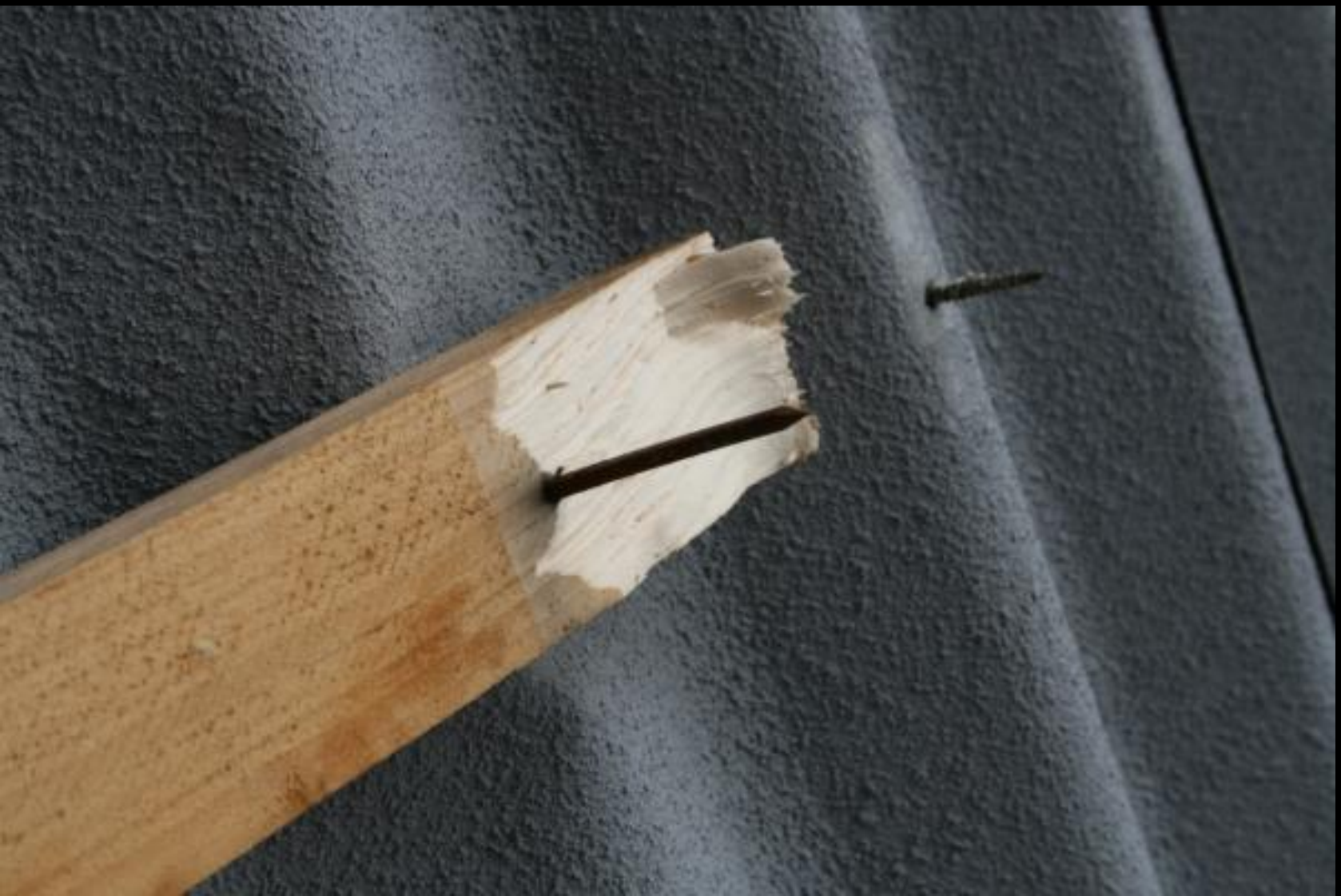
- High withdrawal strength for smooth nail encourage the use of smooth nails for fastening of eg. roof battens
  – which might cause wind storm damage

Roof of steel plates

- 300 m^2 blew off
- Wind speed far from characteristic
- Other part of the roof blew off 3 years ago
- No strengthening considered!

Cause

- Battens fastened with smooth nails (square and rusty)



Withdrawal – threaded nails

- Strength parameter must be declared individually
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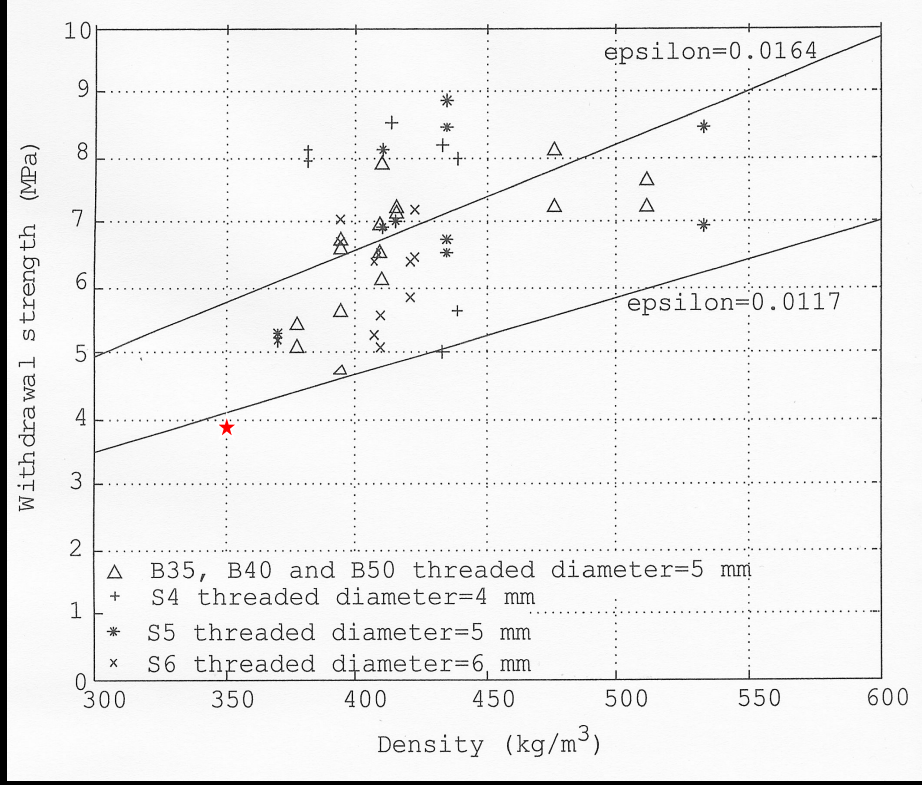
- Danish code has 5 d + point

Withdrawal – screws 1

- Very complicated formula given and only for "old fashioned" screws with d = 6-12 mm
- The simple formula 0.035 d ℓ_{pen} ρ can replace within 10% for d = 6-10 mm
- ITT will give a single strength parameter, independent on e.g. length. A possible diameter dependency will be included in declared parameter
- Separate spacing requirements for withdrawal and only for timber thickness 12d (which members thickness?)

Withdrawal – screws 2

- No significant dependency on diameter for d = 4-6 mm
- Connector screws and modern wood screws similar
- Fits well with (simplified) Eurocode formula



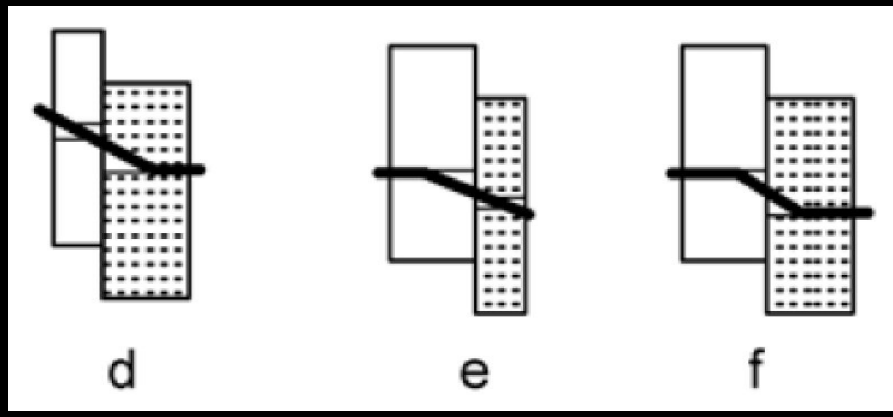
Laterally loaded fasteners

- Nails, timber to timber
- Screws, timber to timber
- Steel to timber

Laterally loaded nails – timber to timber

Eurocode:

- Dowel load capacity from Johansen-theory with embedment strength and yield moment of fastener
- Rope-effect from friction and inclination



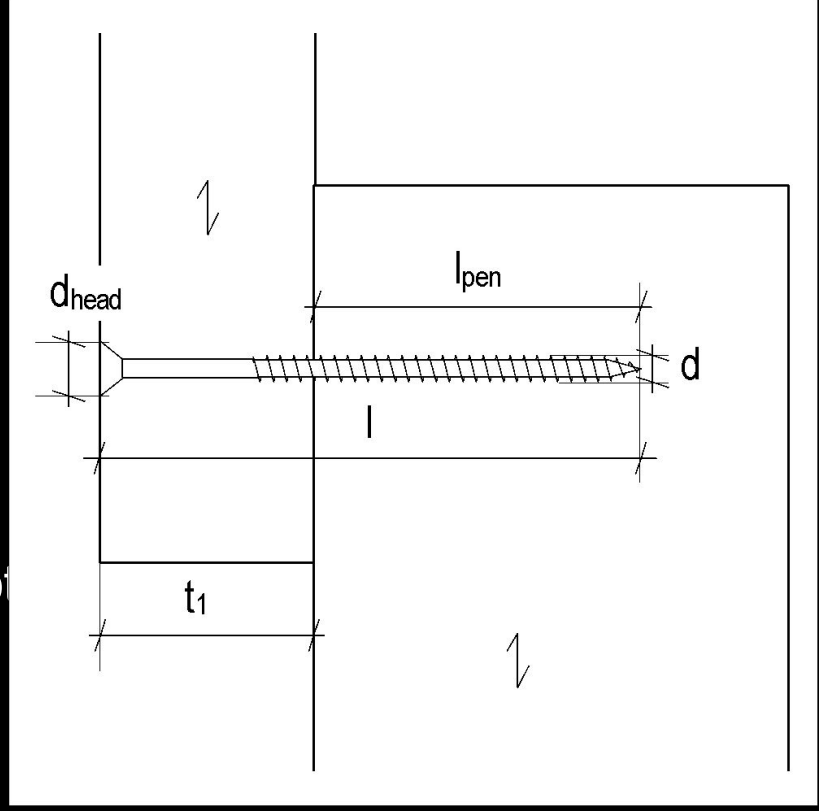
Danish code:

- Presupposes failure-mode f
  - mode e not possible due to required penetration length
  - mode d somewhat prevented by the head
- Rope-effect included by reduced penetration length for threaded nails

d
e
f

Laterally loaded screws

- Eurocode still focus on screws with smooth shank penetrating into pointside
- Eurocode suggests $d_{eff} = 1.1 \times d_{root}$ for the treaded part of screws



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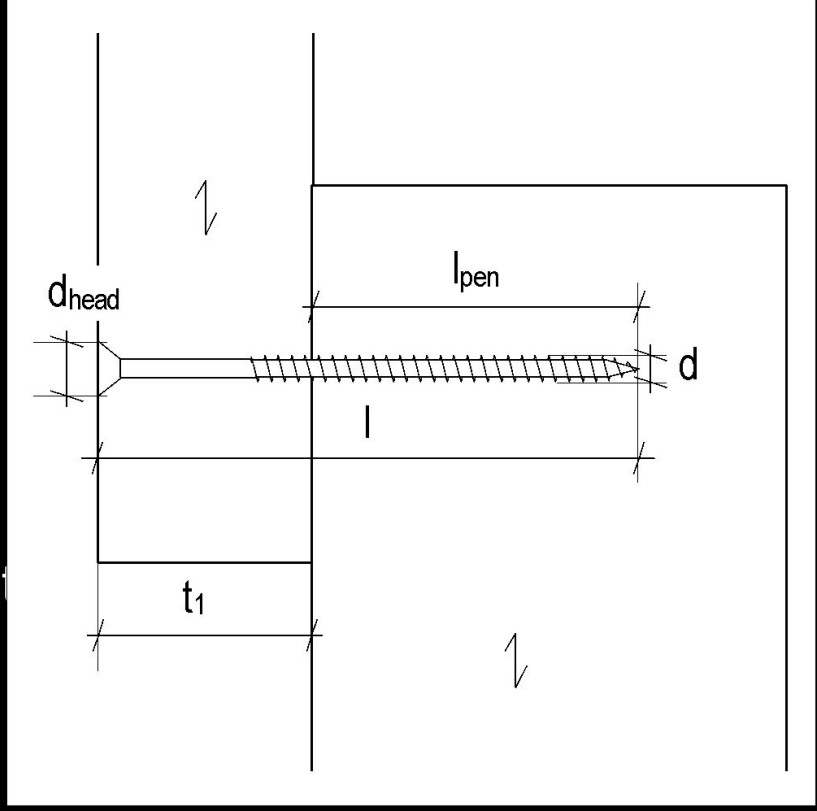

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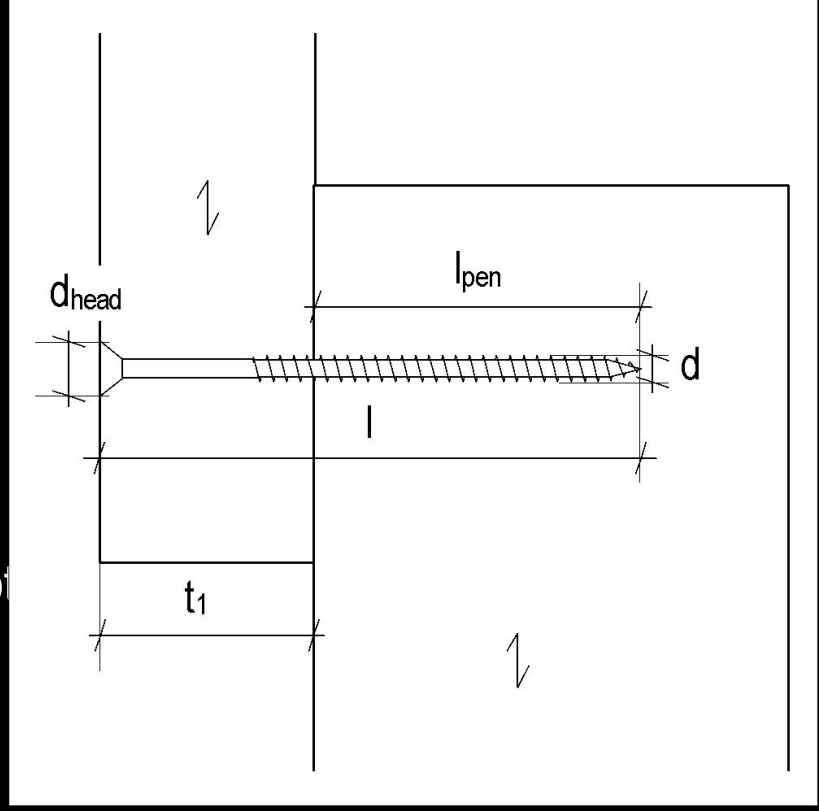
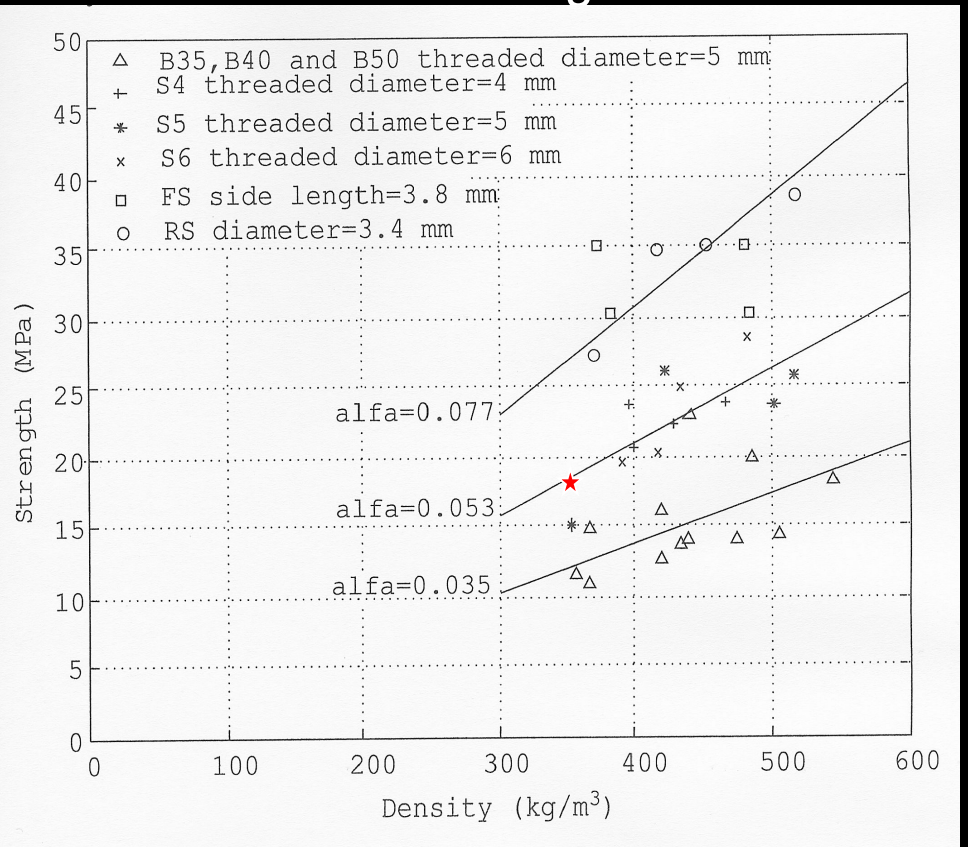
- d_{eff} not likely to be the same for embedment strength f_h and yield moment M_y when measured
- prEN 14592 does not deal with neither d_{eff} nor f_h
- Most straight forward to declare f_h (for diameter d) and M_y

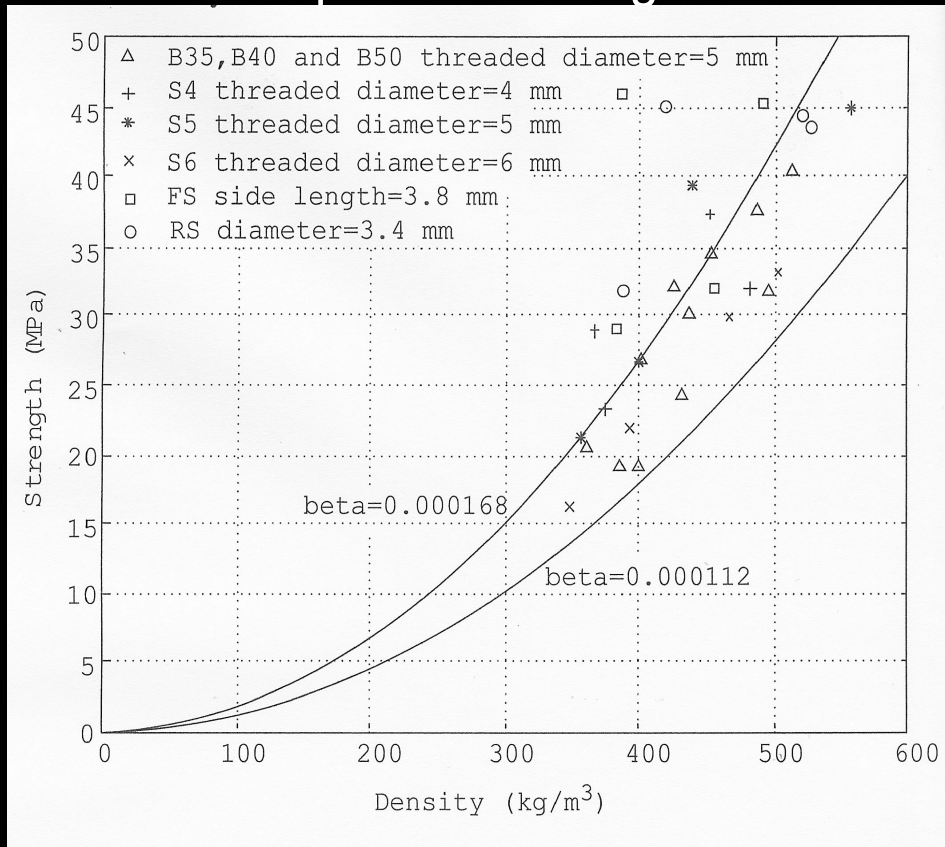


Measured embedment strength for screws

- $d_{root} / d \sim 0.6 \Rightarrow d_{eff} = 1.1 \times d_{root} = 0.66\ d$
- Measured reduction factor for screws 0.45 – 0.7
- Hansen assumes factor to depend on surface roughness

Parallel to grain < Perpendicular to grain





Laterally loaded nails - steel to timber

Eurocode:

- Separate formulas for thick and thin steel-plates (head fixed against rotation or not)
- Thick plate $t \geq d$, thin plate $t \leq d/2$

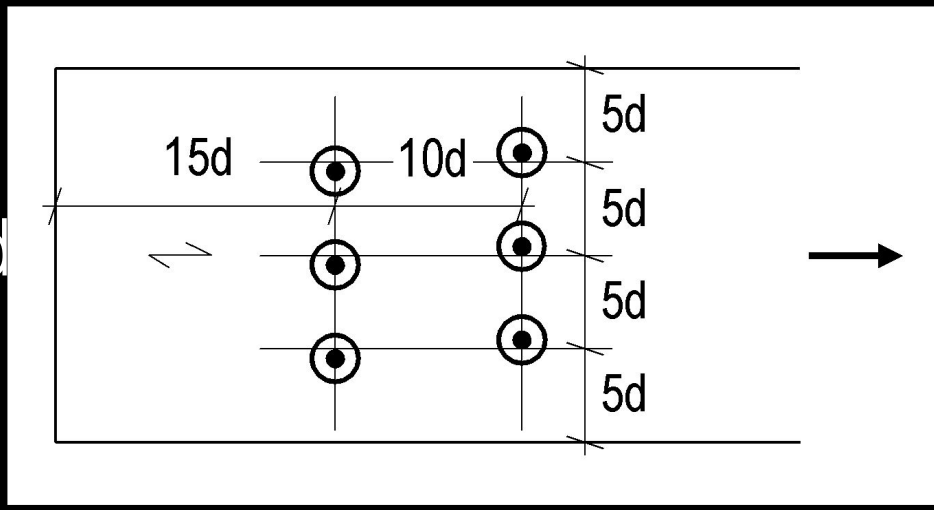
Danish code:

- Head assumed fixed against rotation
- Typical d = 4 mm and t = 2 mm
- Timber to timber strength increased by 25 % (larger rope-effect when not pull-through)

Higher values will appear in an ETA-agreement for most commonly used connector nails and screws
(smaller penetration length, larger rope-effect, fixed head)

Spacing parallel to grain

- If fasteners not staggered 1d
  Eurocode 5 requires increased spacing (14d)
  - or reduced load capacity



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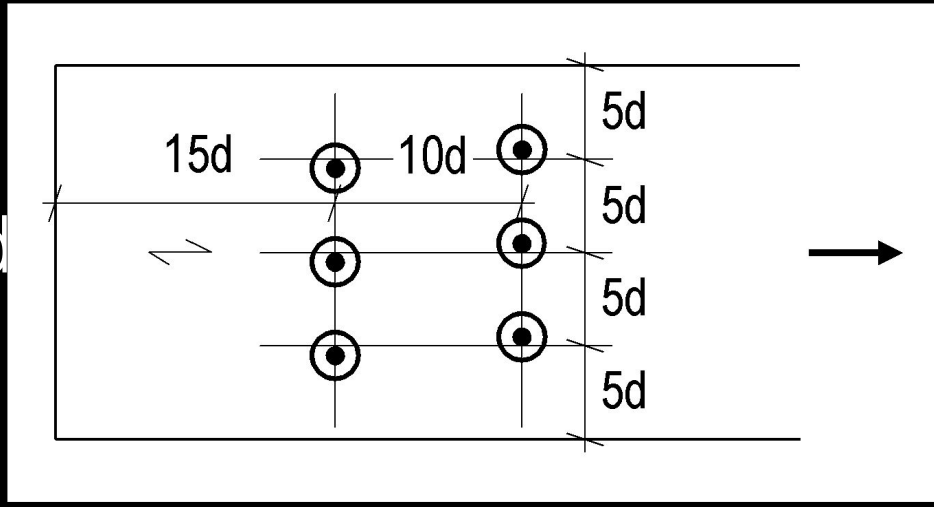

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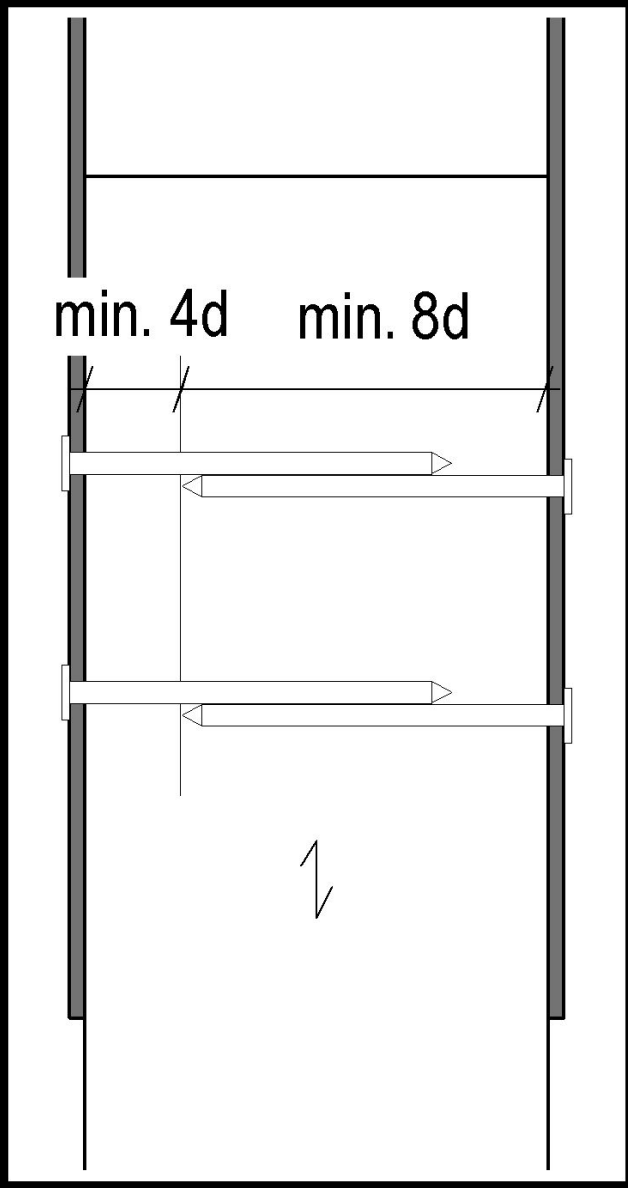
Steel connector plates:

- Spacing can be reduced by factor 0.7
- Not possible to stagger
- Not specified if increased spacing requirement can be reduced by 0.7
- Very questionable if staggering is meaningful for small diameters

Common connection not allowed by EC5

- 45 mm member with connecter-plates on both sides
- Eurocode requires 4d from point to opposite site
  Minimum member thickens for d = 4 mm:
  (4 + 8)d = 48 mm
- Danish code requires only 3d from point to opposite site



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- For types of fasteners covered by Eurocode 5 the strength parameters are mostly - but not always - conservative
- The dependency on density should in general be similar for nails and screws
- Strict rules are needed for correcting measured strength parameters for density
- Preferable to carry out tests with a natural span of densities rather than a fixed density

Conclusions 2

- Minimum penetration lengths appears very conservative
- Correction for changing moisture content might be unsafe for withdrawal of smooth nails but irrelevant for threaded nails and pull-through

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- Correction for changing moisture content might be unsafe for withdrawal of smooth nails but irrelevant for threaded nails and pull-through
- For screws either embedment strength for diameter of thread or effective diameter should be a declared parameter
- Spacing requirement in grain direction unnecessary and unclear for connector plates
- Replacing the Danish timber code with Eurocode 5 reduces the load capacities of most fasteners significantly
- Rules for two-sided nailing a catastrophe for Danish construction