TECHNICAL REPORT

Design of Glued-in Rods for Timber Connections

TR 070

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EUROPEAN ORGANISATION FOR TECHNICAL ASSESSMENT

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Contents

1 SCOPE OF THE TECHNICAL REPORT

This Technical Report (TR) covers the design of glued-in rods for timber connections in glued laminated timber (GLT) and glued solid timber (GST), cross laminated timber (CLT) laminated veneer lumber (LVL) or glued laminated timber of laminated veneer lumber.

This Technical Report (TR) covers glued-in rods with the following adhesive types:

- two-component epoxy adhesive or
- two-component polyurethane

assessed according to EAD 130006-00-0304. This Technical Report (TR) does not cover the design of adhesives for on-site gluing (except for factory-like conditions).

Several provisions of this Technical Report (TR) may apply to repair and upgrading of existing timber structures, including (cracked/fissured) solid wood beams. For adhesives for on-site repair or applications with solid timber additional provisions need to be taken into account. Such provisions are not part of this Technical Report (TR).

This Technical Report (TR) also covers glued–in rods in surface treated wood. It does not cover glued-in rods in modified and stabilized wood with considerably reduced swelling and shrinkage properties, e.g. such as acetylated wood, heat treated wood, polymer impregnated wood and preservative treated wood.

The joints are intended for load bearing timber structures not subjected to temperatures more than 60 °C over a longer time period in service classes 1 and 2 which are loaded predominantly static or quasi static according to EN 1990 and EN 1991-1-1.

This Technical Report (TR) is based on the Annex A of prEN 17334 (11.2018). Once EN 1995-1-1 includes design rules for glued-in rods these should be applied.

2 SPECIFIC TERMS AND DEFINITIONS USED IN THIS TR

For the purposes of this Technical Report (TR), the terms and definitions given in EN 923 and the following apply.

two component epoxy adhesive	thermosetting synthetic resin derived from an exothermic polymerization reaction of an epoxide group with amines, acid anhydrides, phenols, alcohols or thiols
two component polyurethane (PUR) adhesive	urethane polymers which are cross-linked by the reaction between polyol or polyamine with isocyanate
service class 1	climatic conditions characterized by a moisture content in the 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 *Note: In service class 1, which comprises typical indoor conditions, the average moisture content in most soft-woods will not exceed 12 %*
service class 2	climatic conditions characterized by a moisture content in the 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 *Note: In service class 2, to which most covered exterior conditions belong, the average moisture content in most softwoods will not exceed 20 %*

3 SYMBOLS

α	Angle included by the axis of the timber member and the steel rods
a_1	minimum distance of axially loaded glued-in rods (normal to grain direction)
a_2	minimum distance of axially loaded glued-in rods (in grain direction)
$a_{1,c}$, $a_{2,c}$	minimum edge distance of axially loaded glued-in rods
$a_{3,t}$	minimum distance of axially loaded glued-in rods (loaded end grain face)
$a_{3,c}$	minimum distance of axially loaded glued-in rods (unloaded end grain face)
$a_{4,t}$	minimum distance of axially loaded glued-in rods (loaded edge)
$a_{4,c}$	minimum distance of axially loaded glued-in rods (unloaded edge)
A_{ef}	stress design relevant cross-section of steel rod
β	Angle included by the axis of the timber member and the steel rods
b	width of timber member
d	nominal diameter of steel rod in mm
$F_{ax,Rd}$	design value for the withdrawal (pull-out) capacity
$F_{v,Ed}$	design values of shear force
$F_{v,Ed,1}$, $F_{v,Ed,2}$	design values of shear force at both sides of the connection
$f_{vr,d}$	design value of bond shear strength as given in the ETA
$f_{vr,k}$	characteristic value of bond shear strength as given in the ETA
$f_{y,d}$	design value of yield strength of steel rod
$f_{y,k}$	characteristic value of yield strength of steel rod
$F_{90,Rd}$, $F_{90,Rk}$	design value and characteristic value of resistance to tension perpendicular to grain of the loaded member
γ_M	Partial factor for material properties, also accounting for model uncertainties and dimensional variations
h	depth of timber member
h_e	projected rod embedment length perpendicular to grain
k_{mod}	Modification factor for duration of load and moisture content
l_a	bond length of steel rod in mm
$l_{a,min}$	minimum bond length

4 DESIGN PROCEDURE FOR GLUED-IN RODS IN GLT, GST, LVL AND CLT [1)]

[1)] The specified provisions apply to fibre parallel applications of rods in edge-glued, ungrooved timber layers of CLT with a minimum distance of 8 mm from the hole peripheries to the next cross layers.

4.1 Loading parallel to rod axis

4.1.1 Failure mechanism

For ultimate load design of steel rods loaded parallel to rod axis the following failure mechanism shall be taken into account:

- failure of steel rod
- failure of bond line or wood-adhesive interface along rod-wood bond length
- failure of wood adherent
- block shear failure of a group of glued-in rods

4.1.2 Uneven loading

In case of multiple glued-in rods where an uneven loading of the individual rods cannot be excluded, than the load capacity of the steel rod and not of the wood or the bond line shall be considered as relevant.

4.1.3 Minimum distances

The minimum distances between the rods and from the edges are given in Table 4.1, and Figure 4.1.

4.1.4 Design value for withdrawal

The design value for the withdrawal (pull-out) capacity of a single glued-in rod can be calculated as given in equation (4.1).

$$F_{ax,Rd} = min\begin{cases} f_{y,d} \cdot A_{ef} & (Failure\ of\ steel\ rod) \\ \pi \cdot d \cdot l_a \cdot f_{vr,d} & (Failure\ of\ bond\ line) \\ \pi \cdot d \cdot l_a \cdot f_{vw,d} & (Failure\ of\ wood\ adherent) \end{cases} \quad (4.1)$$

Note: The design values for the yield strength of the steel rod and of the bond shear strength may be determined according to

$$f_{y,d} = \frac{f_{y,k}}{\gamma_{M,steel}} \quad (4.2)$$

$$f_{vr,d} = \frac{f_{vr,k} \cdot k_{mod}}{\gamma_{M,wood/adhesive}} \quad (4.3)$$

The bond length $l_{a,\text{in}}$ (in mm) shall be at least

$$l_{a,min} = max\{0{,}5 \cdot d^2; 10\ d\} \quad (4.4)$$

4.1.5 Loading parallel to the grain

For rods glued-in parallel to grain the tension strength of the wood at the end of the steel rod shall be verified. Per rod the effective cross-sectional area of the wood shall be taken maximally as 36 d^2.

4.1.6 Loading non-parallel to the grain

In case axially loaded glued-in rods are used for joints where the rods and the axis of the timber member include an angle $\beta \leq 90°$ (see Figure 4.2) the tension stresses perpendicular to grain caused by the load component perpendicular to grain shall be verified as

$$\frac{F_{v,Ed}}{F_{90,Rd}} \leq 1 \tag{4.5}$$

where

$$F_{v,Ed} = max\begin{cases} F_{v,Ed,1} \\ F_{v,Ed,2} \end{cases} \tag{4.6}$$

$$F_{90,Rd} = \frac{F_{90,Rk} \cdot k_{mod}}{\gamma_M} \tag{4.7}$$

$$F_{90,Rk} = 14 \cdot b \sqrt{\frac{h_e}{\left(1-\frac{h_e}{h}\right)}} \quad \text{in N, dimensions in mm} \tag{4.8}$$

($F_{90,Rk}$ as given in equation (4.8) applies only to softwoods)

$$h_e = \sin\beta \cdot l_a \tag{4.9}$$

Table 4.1: Minimum distances of axially loaded glued-in rods

Steel rods glued-in parallel to grain	Steel rods glued-in perpendicular to grain
a_2 = 5 d $a_{2,c}$ = 2,5 d	a_1 = 4 d a_2 = 4 d $a_{1,c}$ = 2,5 d $a_{2,c}$ = 2,5 d

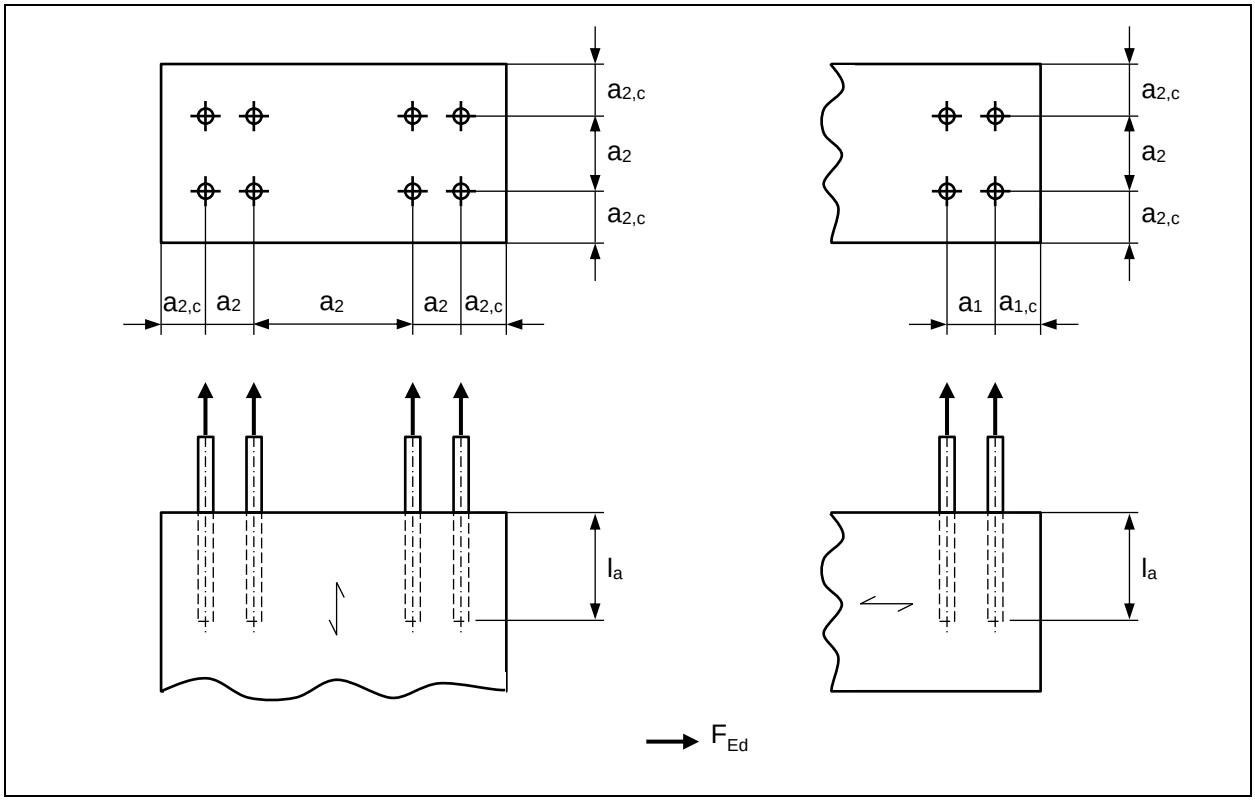

Figure 4.1: Definition of minimum distances of axially loaded glued-in rods

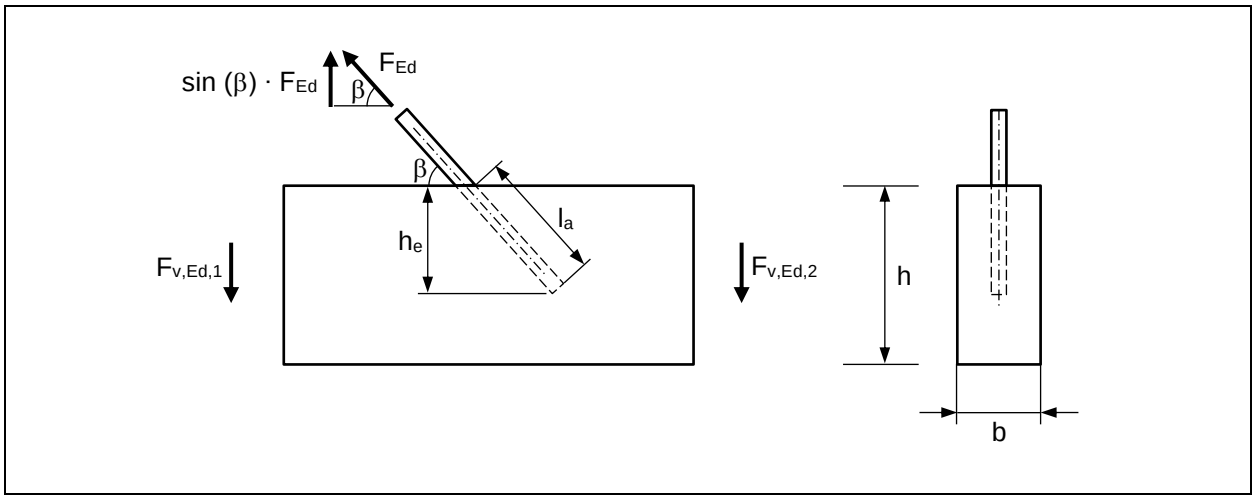

Figure 4.2: Joint with inclined glued-in rods (screw-joint)

4.1.7 Block shear failure

For a group of axially loaded rods the occurrence of a block shear failure parallel to the grain shall be verified against the load component acting parallel to the grain. The higher characteristic load resulting from either the envelope area around the rod group multiplied by characteristic shear strength of the wood or the net cross section at the end of the rod group multiplied by the characteristic tensile strength shall be considered relevant. An example of the net cross section is given in Figure 4.3.

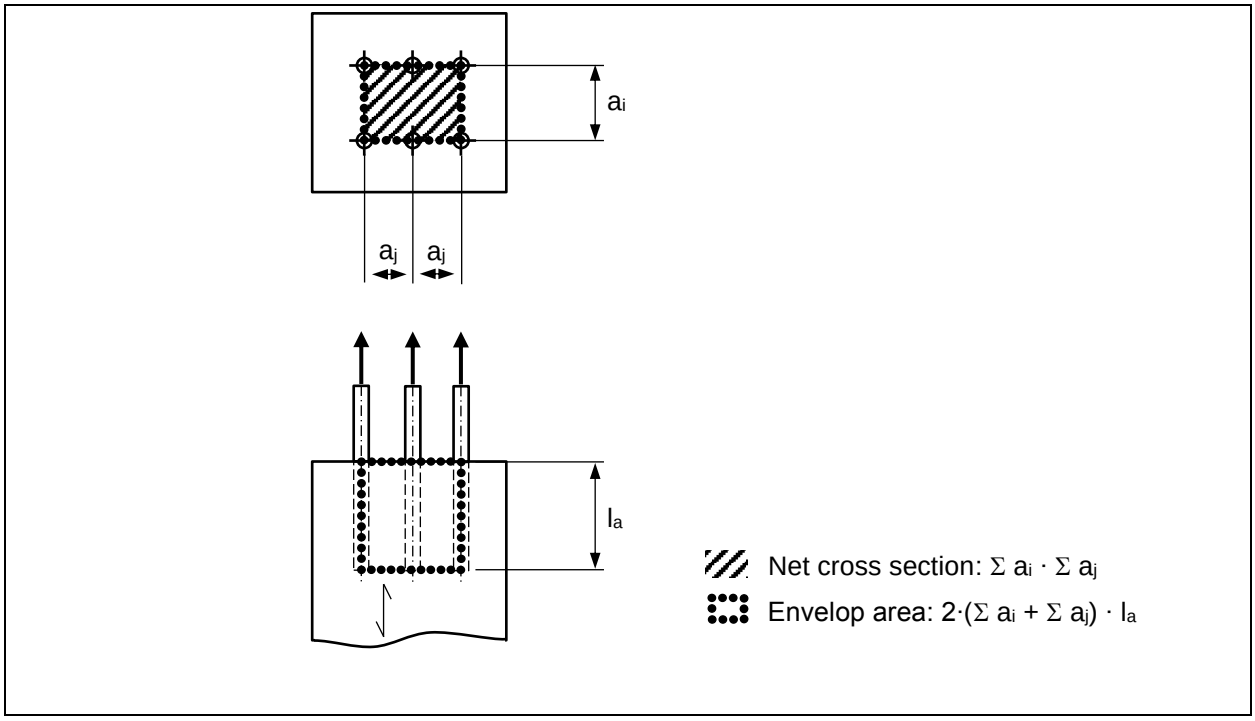

Figure 4.3: Example for net cross section and envelop area

4.2 Lateral load-carrying capacity of glued-in rods

4.2.1 General

For the determination of the lateral load-carrying capacity of the glued-in steel rod the design provisions specified for laterally loaded dowel-type fasteners in EN 1995-1-1, chap. 8.2, apply. In case of rebars the nominal diameter shall be taken for diameter d.

Unless specified different hereinafter, further the rules specified in EN 1995-1-1, chap. 8.7, for screws and threaded steel rods apply.

4.2.2 Minimum distances

The minimum distances for laterally loaded steel rods glued-in parallel to grain are specified in Table 4.2 and Figure 4.4. The minimum distances for laterally loaded steel rods glued-in perpendicular to grain are specified in Table 4.3 and Figure 4.5.

Table 4.2: Minimum distances of laterally loaded steel rods glued-in parallel to grain

a_2	$a_{2,c}$	$a_{2,t}$
5 d	2,5 d	4 d

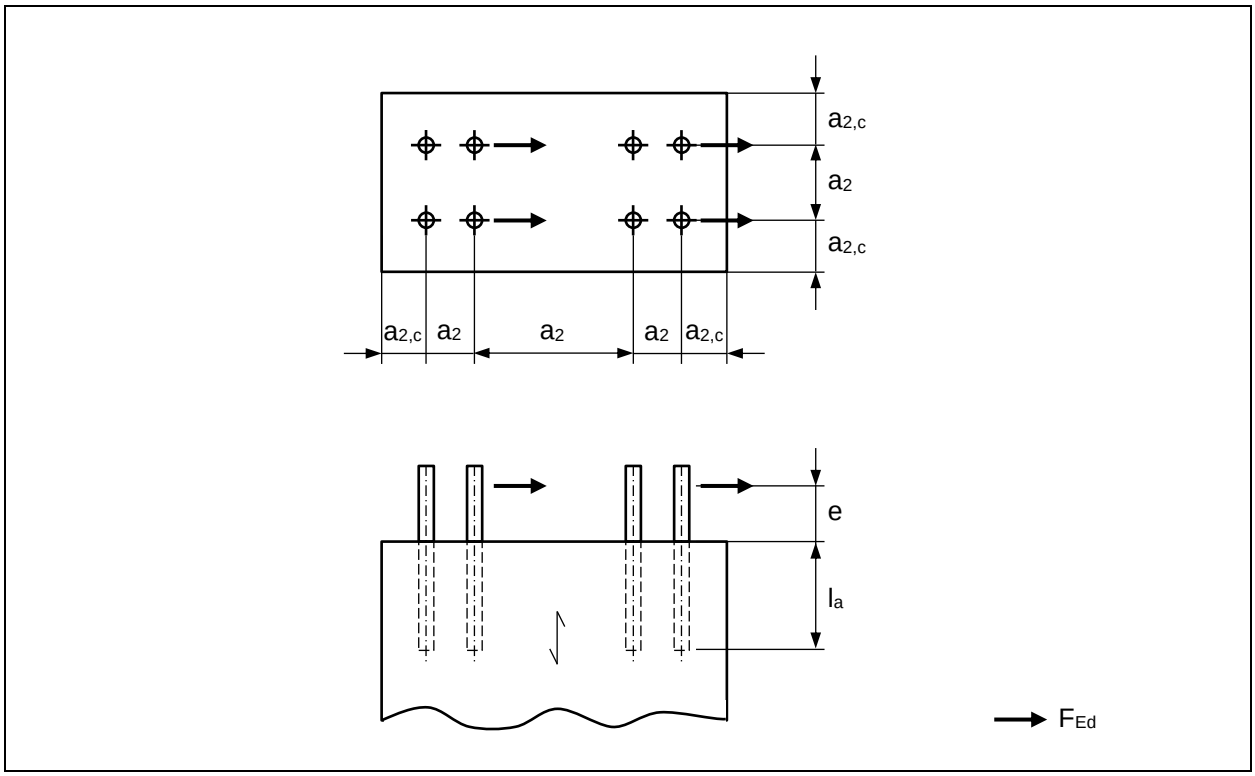

Figure 4.4: Definition of minimum distances of laterally loaded steel rods glued-in parallel to grain

Table 4.3: Minimum distances of laterally loaded steel rods glued-in parallel to grain

Distances		Angle	Minimum distances
a_1	(in fibre direction)	$0° \le \alpha \le 360°$	$(3 + 2 \mid \cos \alpha \mid) d$
a_2	(normal fibre direction)	$0° \le \alpha \le 360°$	3 d
$a_{3,t}$	(loaded end grain face)	$-90° \le \alpha \le 90°$	max (7 d; 80 mm)
$a_{3,c}$	(unloaded end grain face)	$90° \le \alpha < 150°$ $150° \le \alpha < 210°$ $210° \le \alpha \le 270°$	max ($a_{3,t} \mid \sin \alpha \mid$) d; 3 d) 3 d max ($a_{3,t} \mid \sin \alpha \mid$) d; 3 d)
$a_{4,t}$	(loaded edge)	$0° \le \alpha \le 180°$	max [(2 + 2 sin α) d; 3 d]
$a_{4,c}$	(unloaded edge)	$180° \le \alpha \le 360°$	3 d

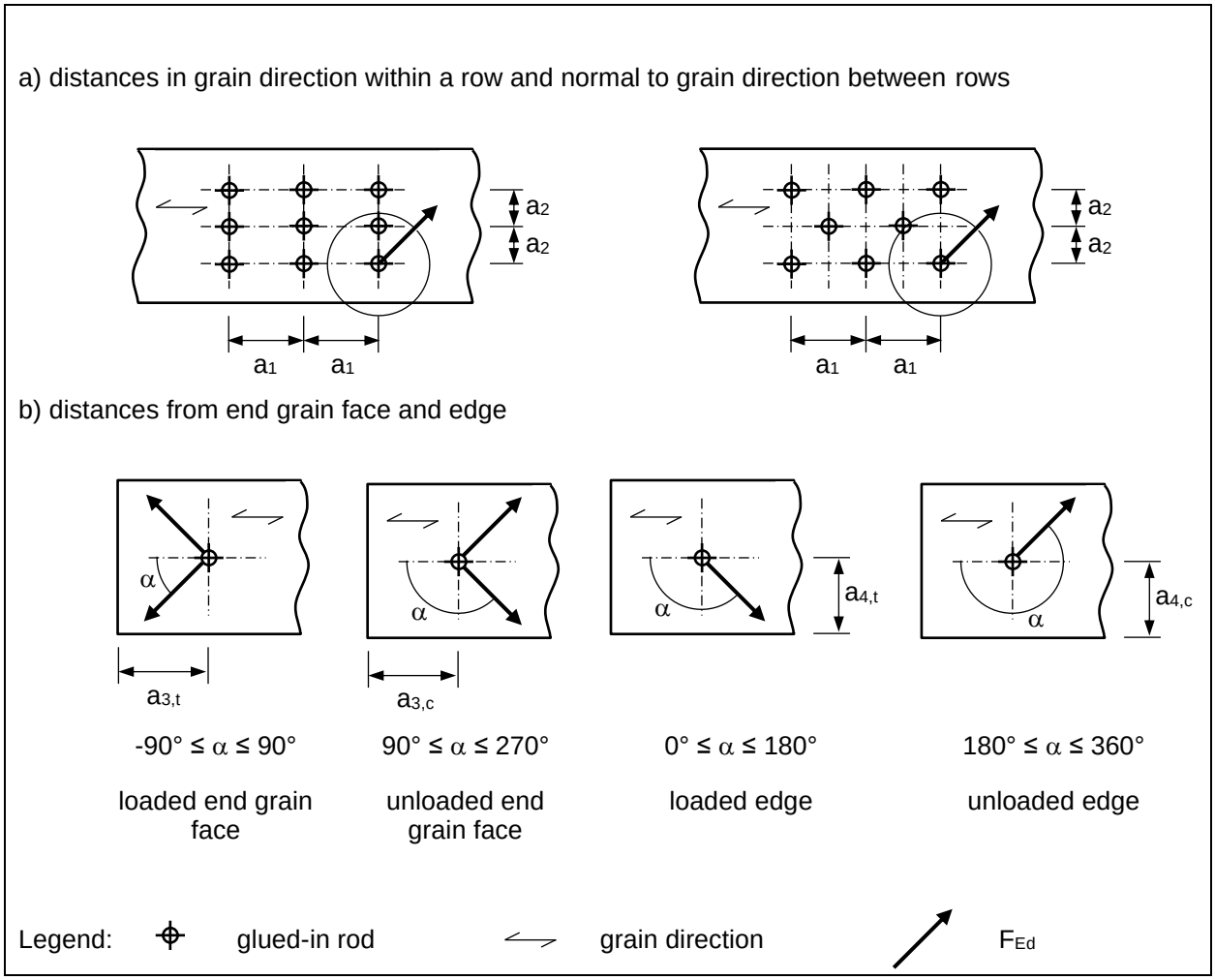

Figure 4.5: Definition of minimum distances of laterally loaded steel rods glued-in perpendicular to grain direction

4.2.3 Characteristic value of embedment strength

In case of rods glued-in perpendicular to grain direction the characteristic value of the embedment strength acc. to EN 1995-1-1, chap. 8.5, can be increased by a factor of 1,25.

In case of rods glued-in parallel to grain the characteristic value of the embedment strength may be assumed as 10 % of the respective values for steel rods glued-in perpendicular to grain.

In case the angle between grain direction and axis of glued-in rod lies between 0° and 90°, then the characteristic value of the embedment strength may be determined by linear interpolation.

4.2.4 Eccentric lateral load

n case the lateral load acts at a distance e to the end grain face (see Figure 4.5), this has to be considered in ultimate limit state design of the joint.

4.3 Combined axial and lateral loading

In case of combined lateral and axial loading of glued-in steel rods it shall be verified that equation (4.10) is fulfilled.

$$\left(\frac{F_{la,Ed}}{F_{la,Rd}}\right)^2 + \left(\frac{F_{ax,Ed}}{R_{ax,Ed}}\right)^2 < 1 \qquad (4.10)$$

5 REFERENCE DOCUMENTS

As far as no edition date is given in the list thereafter, the publication in its current version is of relevance.

EAD 130006-00-0304 (xx.2019)	Glued-in rods for timber connections
prEN 17334 (11.2018)	Glued-in rods in glued structural timber products – Testing, requirements and bond shear strength classification
EN 1995-1-1	Eurocode 5: Design of timber structures – Part 1-1: General – Common rules and rules for buildings