



TECHNICAL GUIDE

HIT-RE 500 V4

Glued-in rod solution for timber
connection and reinforcement
applications



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1. Introduction

Timber is increasingly adopted in modern construction due to its **renewability**, **material efficiency**, and **favorable structural performance**. Engineered timber products such as GLT, CLT and LVL help enable high-performance building systems in both residential and commercial environments (Fig. 1.1).

As timber construction continues to evolve toward more advanced and demanding structural applications, connection technologies have become increasingly important in help to ensure structural performance and safety. Among these solutions, **glued-in rod systems** have gained attention as an **efficient method for creating high-strength, concealed connections in timber structures**. In glued-in rods process, boreholes are first drilled in the timber members with the required diameter and embedment depth according to the design. The holes are cleaned to remove dust and then epoxy adhesive is injected into the boreholes, and threaded rods or reinforcing bars are inserted to ensure full bonding. The adhesive is allowed to cure, forming a monolithic connection. The process can be used for timber-to-timber, timber-to-steel and timber-to-concrete connections. Furthermore, glued-in rods (GiR) are an effective solution for reinforcing existing timber structures, increasing their resistance to tension perpendicular to the grain.



Fig. 1.1: Example of engineered timber base materials used in the frame of a building

1.1 Applications

Hilti GiR systems are commonly used for both **connections** and **reinforcement** applications. Due to the system's ability to transfer axial and transverse forces efficiently, GiR is especially suitable for tension-, compression- and moment- loaded applications as well as for various reinforcement applications, where the GiR is used as "reinforcement" perpendicular to the grain.

1.1.1 Connections

Depending on the structural configuration and material interface, several connection types can be realized. **Timber-to-timber** connections can be found in truss girder connections (Fig. 1.2a). **Timber-**

to-steel connections using GiR are commonly applied where timber elements are connected to steel plates or profiles, e.g., for wind bracings (Fig. 1.2b) or column to foundation connections (Fig. 1.2c). The rods are bonded into the timber and mechanically connected to steel components through welding or bolting.

In **timber-to-concrete** connections, GiR is embedded into the timber element while the opposite end is anchored into concrete using post-installed anchorage systems (Fig. 1.2d). These applications are most commonly used in interior low-moisture conditions. Fig. 1.2 shows common connection applications with GiR.



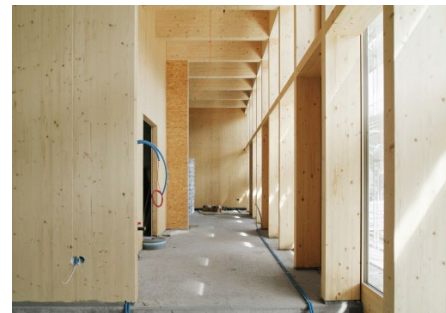
a) Truss girder



b) Timber-to-steel plate



c) Column to foundation



d) Timber-to-concrete

Fig. 1.2: Timber-to-timber, timber-to-concrete and timber-to-steel connections

1.1.2 Reinforcement

GiR system can also support reinforcement of timber structures as shown in Fig. 1.3. The existing structural elements such as beams with straight, curved, notched and openings can be strengthened. Due to high **transverse compression** forces in the support areas, compression reinforcement may be required (Fig. 1.3a). In cases with **notches**, high shear forces near the supports may need shear reinforcement (Fig. 1.3b). **Openings** can induce high concentrations of shear stress in timber members, which can be compensated by reinforcing the areas around the holes (Fig. 1.3c). Highly stressed areas, **curved beams**, especially where tension perpendicular to the grain occurs, can be efficiently strengthened by adding internal reinforcing elements (Fig. 1.3d).



a) Transverse compression reinforcement



b) Notched reinforcement



c) Holes in beams



d) Curved beam

Fig. 1.3: GiR in reinforcement applications

Hilti glued-in rod solution presented in this technical guide addresses many of the aspects highlighted above. It is the solution described in Section 2 and includes the available installation methods and required accessories. Design methods and verification approaches for the different applications are presented in Section 3, providing practical guidance for the reader. Sections 4 and 5 describe Hilti glued-in rod software module and present calculation examples for connections loaded under pure tension, transverse compression strengthening and/or with a bending moment and transverse compression reinforcement.

2. Hilti Glued-in Rod solution (GiR)

Hilti GiR solution offers a reliable method for timber connections and reinforcement points holding a European Technical Assessment (**ETA-20/0834** [1]) according to European Assessment Document (**EAD**) **130006-00-030** [2]. The system consists primarily of **Hilti HIT-RE 500 V4 and threaded rods or reinforcing bars** available in various diameters, strength grades, and corrosion-resistant options (Fig. 2.1). This system is intended to be used on

- On load-bearing timber-to-timber, timber-to-concrete and timber-to-steel connections
- As a reinforcement element in glued laminated timber (GLT) or glued solid timber (GST) (according to EN 14080 [3])
- On cross laminated timber (CLT) bonded at the edges (according to EN 16351 [4])
- On laminated veneer lumber (LVL) made of softwood of wood species European spruce (*Picea abies*), pine (*Pinus sylvestris*) or fir (*Abies alba*) (according to EN 14374 [5])

The glued-in rods are mainly used to transfer tension or compression forces. For this application the load-bearing timber structures should not be exposed to temperatures above 60°C over a longer period. Hilti HIT-RE 500 V4 shall be subjected to static and quasi-static actions only and Hilti HIT-RE 500 V4 is intended to be used in **service classes 1 and 2** according to EN 1995-1-1:2004 [6]. The service classes are defined in Table 2.1.

Table 2.1: Service classes according to EN 1995-1-1:2004

Service class	Definition
1	Characterized by a moisture content in the materials corresponding to a temperature 20°C and the relative humidity of the surrounding air only exceeding 65% for a few weeks per year¹. 1: The average moisture content in most of soft woods will not exceed 12%.
2	Characterized by a moisture content in the materials corresponding to a temperature 20°C and the relative humidity of the surrounding air only exceeding 85% for a few weeks per year². 2: The average moisture content in most of soft woods will not exceed 20%.



Fig. 2.1: Hilti HIT-RE 500 V4 glued-in rods

2.1 Product description and installation

As already mentioned, Hilti glued-in rod (GiR) solutions for timber connection and reinforcement are composed of a two-component epoxy adhesive (HIT-RE 500 V4) and steel threaded or reinforcing bars. The steel element is placed into a drill hole which is filled with HIT-RE 500 V4 to achieve bonding between the rod, the adhesive system and the timber element according to ETA-20/0834 and Hilti IFU:

- Threaded rods: **6–30 mm**
- Reinforcing bars: **6–28 mm**
- Minimum embedment: **10d or 100 mm**
- Maximum embedment: **1000 mm**
- Minimum edge distances and spacing axially loaded rods follow EOTA TR 070 [7], Table 4.1
- Optional use of **debonding sleeves** allow reduced edge distances and spacing (2,5 and 5,0 to 2,0 and 4,0 diameters and enable ductility design in connection applications.

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

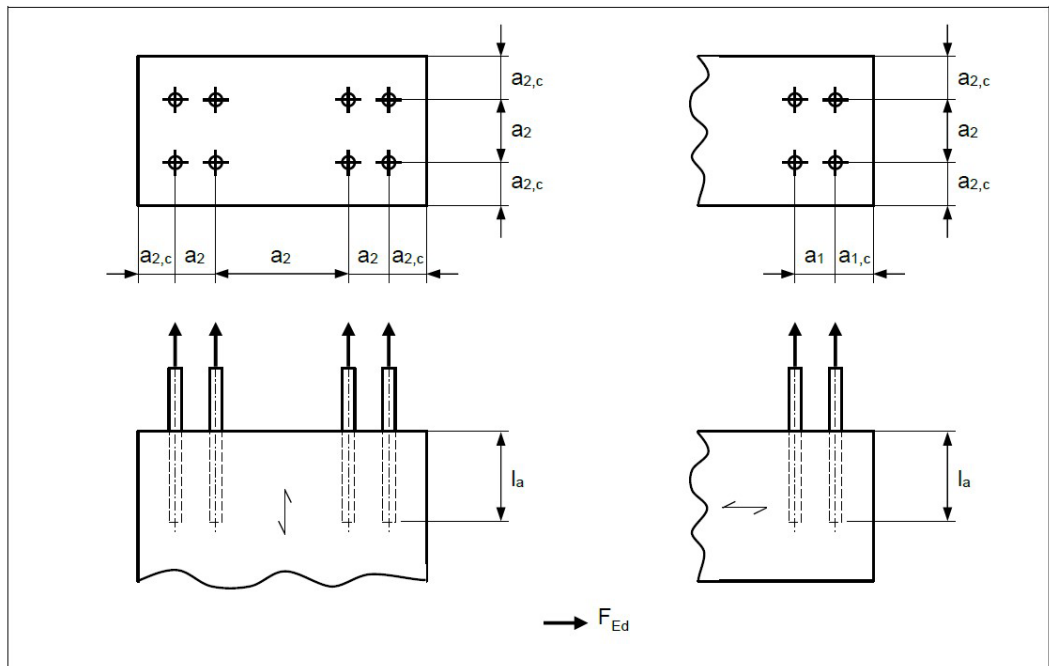


Fig. 2.2: Minimum distances of axially loaded rods ([7])

The threaded rod or reinforcing bars must be installed following Hilti GiR instructions for use (IFU), and two main options are possible: 1) **Bypass filling** and 2) **Direct filling**.

2.1.1 Bypass filling

Bypass filling consists of introducing mortar into the borehole via lateral pilot holes with the following process:

1. Drill main and bypass holes
2. Clean with compressed air (≥ 6 bar)
3. Install centering rings (HIT-CR) when required, i.e. for borehole diameters > 2 mm larger than the threaded rod diameter
4. Insert rod and fix in position
5. Inject mortar through pilot holes until full.



Fig. 2.3: Hilti GiR installation with bypass filing

The bypass filling installation steps explained in Fig. 2.4.

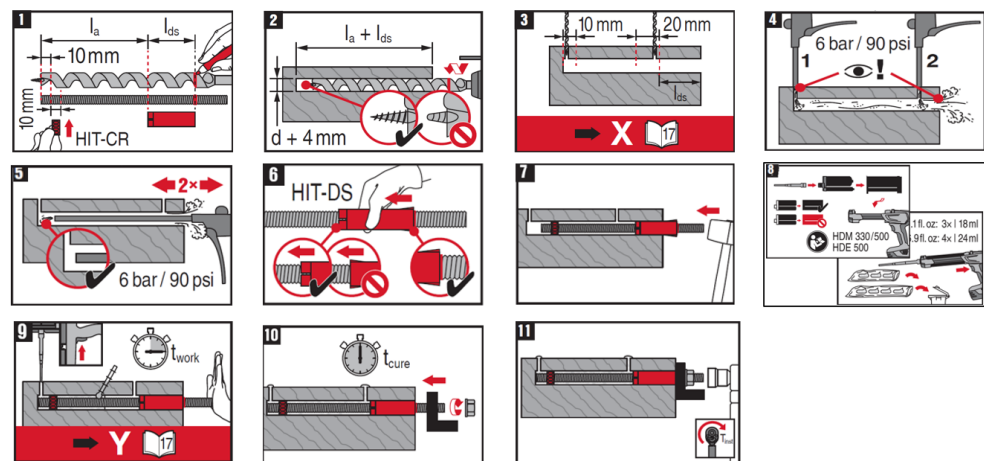


Fig. 2.4: Hilti GiR installation steps with bypass filing

2.1.2 Direct filling

For direct filling, the mortar is injected into the main borehole using **piston plug (HIT-SZ)** and **extension hose (HIT-VL)**. The installation must be carried out with following:

1. Drill hole
2. Clean hole
3. Fill borehole with mortar from the back
4. Insert rod while rotating slightly
5. Install centering rings (HIT-CR) when required, i.e. for borehole diameters more than 2 mm larger the threaded rod diameter.



Fig. 2.5: Hilti GiR installation with direct filling

The direct filling installation steps are explained in Fig. 2.6.

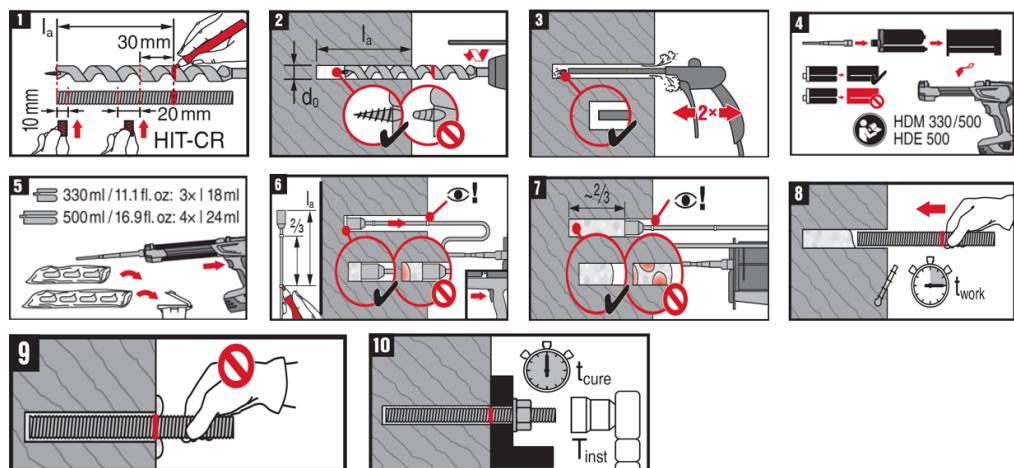


Fig. 2.6: Hilti GiR installation steps with direct filling

2.1.3 Installation hardware

Piston plug and extension hose:

When using direct filling, Hilti offers the piston plug (HIT-SZ) and extension hose (HIT-VL) to help minimize the formation of air voids during installation (Fig. 2.7). Piston plugs with diameters 12-32 mm can be used depending on the bore hole diameter.



Fig. 2.7: Hilti piston plug and extension hose

Centering ring:

When using both installation methods, if borehole diameters are more than 2 mm larger than the threaded rod diameter Hilti centering rings (HIT-CR) are required for proper leveling and to ensure that the steel element is adequately surrounded by the mortar (Fig. 2.8). Centering rings are available for threaded rods with diameter between M12 and M24.



Fig. 2.8: Hilti centering ring

Debonding sleeve:

When using bypass filling as the installation method, you can use the Hilti debonding sleeve (HIT-DS) (Fig. 2.9). When the debonding sleeve is used, the drilling depth needs to be increased by the length of the sleeve (5D). The drilling diameter also needs to exceed the diameter of the rod or reinforcing bar by 4 mm. The debonding sleeve must be inserted through the threaded rod and positioned in the section where the load is applied. The rod can be then inserted into the borehole. The debonding sleeves are available for threaded rods of diameter M16, 20 and 24. With the updated ETA-20/0834 for Hilti HIT-RE 500 V4, new debonding sleeves help reduce the risk of timber splitting. This element helps to reduce edge distances and spacing from 2.5 and 5.0 (see Fig. 2.2) to 2.0 and 4.0 diameters, respectively . Another key benefit of the **debonding sleeve** is that it helps **to enable ductile design according to EN 1995-1-1:2025** in tension-loaded connections as explained in Section 3.5.



Fig. 2.9: Hilti debonding sleeve

Electrical dispenser:

The HDE 500-22 electrical dispenser provides more productive injection with mortar dosing to help minimize wastage (Fig. 2.10).



Fig. 2.10: Hilti electrical dispenser, HDE 500-22

Relevant hardware which can be used for each installation method is listed in Table 2.2.

Table 2.2: Hilti installation hardware list

 Bypass filling	Electrical dispenser  HDE 500-22	Threaded rod HAS(-U)/HIT-V/AM 	Epoxy mortar HIT-RE 500V4 
		Centering ring HIT-CR 	Debonding sleeve HIT-DS 
 Direct filling	Electrical dispenser  HDE 500-22	Threaded rod HAS(-U)/HIT-V/AM 	Epoxy mortar HIT-RE 500V4 
		Centering ring HIT-CR 	Piston plug and extension hose HIT-SZ + HIT-VL 

2.1.4 Installation conditions

The surfaces to be bonded must be clean and free of adhesive-repellent substances such as oil, fats, or release agents. The moisture content of timber on the adherent surfaces during gluing shall not exceed 15%, and the moisture content of wood on the adherent surfaces in use shall not exceed 18%. The temperature of the timber and adhesive during gluing may vary between 15 and 30°C, with corresponding working and curing times according to HIT-RE 500 V4 IFU (Table 2.3).

Table 2.3: HILTI RE-500 V4 working and curing times

Temperature [C°]	t _{work} [min]	t _{cure} [h]
15...19	12	4.5
20...29	7	3.5
30	7	1.5

During installation the following parameters shall be monitored and recorded:

- Timber moisture content,
- Temperature during curing and bonding,
- Adhesive and storage life,
- Start and end time of the bonding operation.

3. Design of glued-in rod connections and reinforcement applications

In this technical guide, design methods, verifications and the relevant standards are presented for tension and moment-loaded connections (Table 3.1) as well as transverse compression reinforcement (Table 3.2). As the GiR technology is relatively new, the code landscape is still fragmented and in continuous development. In Table 3.1 and Table 3.2, the applicable codes and guidelines associated with specific verifications are shown. In the following sections and in the worked-out design examples in Section 5, you can find detailed explanations of how the design flow works.

General note: All design verifications presented in this chapter serve as general guidance only. They do not replace project-specific structural design by a qualified engineer. All Hilti products must be used strictly according to ETA-20/0834, the instructions for use (IFU), and applicable standards.

3.1 Design of glued-in rod connection applications

The design must consider all relevant failure modes associated with glued-in rod connections as defined in EOTA TR 070. Typical failure mechanisms include those shown in Fig. 3.1; however, the responsible engineer must verify all modes applicable to the project.

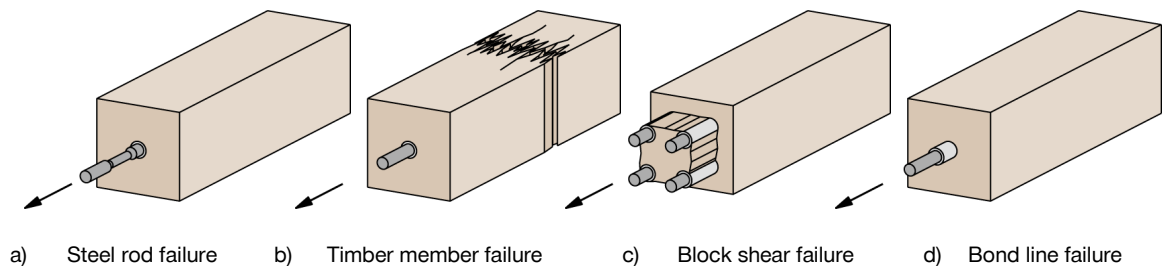


Fig. 3.1: Failure modes in connections

The **design of tension- and moment-loaded connection applications including** worked-out design examples, is presented in Sections 5.1 and 5.2, respectively. The design of GiR can be carried out according to EN 1995-1-1:2004 and EOTA TR 070. In addition to these, EN 1995-1-1:2025 [8] and national annexes such as DIN EN 1995-1-1/NA [9] are also used, particularly for ductility verifications and for other design methodologies that are not covered in the current versions of EN 1995-1-1 and EOTA TR 070. The failure modes shown in Fig. 3.1 must be checked. Table 3.1 shows which standards and guidelines are applicable for specific verifications.

Table 3.1: GiR connection applications, main force effects, relevant failure modes and design methods

Application		Force effects	Failure modes	Design method
Tension		Mainly tension	Steel rod	DIN EN 1995-1-1 NA
			Bond line	EOTA TR 070 + EN 1995-1-1:2025
			Timber member	EN 1995-1-1:2025
			Block shear	EOTA TR 070
			Ductility	EN 1995-1-1:2025
Moment loaded		Tension and compression due to the bending moment	Steel rod (Tension)	DIN EN 1995-1-1 NA
			Bond line	EOTA TR 070 + EN 1995-1-1:2025
			Timber member	EN 1995-1-1:2025
			Block shear	EOTA TR 070
			Ductility	EN 1995-1-1:2025
			Steel rod (Compression)	Z-9.1-791 + EN 1995-1-1:2025
			Steel rod (Shear)	EN 1995-1-1:2025
			Steel rod (Combination)	EN 1995-1-1:2025

3.2 Design of glued-in rod reinforcement applications

The design of the transverse compression reinforcement application and a worked-out design example is included in Section 5.3. The design can be carried out according to EN 1995-1-1:2004, EN 1995-1-1:2025 and aBG Z-9.1-791 [10]. Table 3.2 shows which standards and guidelines are applicable for specific verifications.

Table 3.2: GiR reinforcement application, main force effects, relevant verifications and design methods

Application		Force effects	Failure modes	Design method
Transverse compression reinforcement		Mainly compression	Transverse pressure loaded steel rod (unreinforced)	EN-1995-1-1:2004
			Transverse pressure loaded steel rod (reinforced)	Z-9.1-791 + EN 1995-1-1:2025

3.3 Design value of material property

Design value X_d of a strength property shall be calculated as:

$$X_d = k_{mod} \cdot \frac{X_k}{\gamma_m} \quad \text{EN 1995-1-1:2004, Eq. (2.14)}$$

X_d : design value of a strength property

k_{mod} : modification factor for duration of load and moisture content EN 1995-1-1:2004, Table 3.1

X_k : characteristic value of a strength property

γ_m : material partial factor – 1.3 DIN EN 1995-1-1/NA, Table NA.2

3.4 Design resistance

Design value R_d of a resistance (load-carrying capacity) shall be calculated as:

$$R_d = k_{mod} \cdot \frac{R_k}{\gamma_m} \quad \text{(EN 1995-1-1:2004, Eq. (2.17))}$$

R_d : design value of load carrying capacity

k_{mod} : modification factor for duration of load and moisture content EN 1995-1-1:2004, Table 3.1

R_k : characteristic value of load carrying capacity

γ_M : material partial factor – 1.3 DIN EN 1995-1-1/NA, Table NA.2

Note: γ_{M0} , γ_{M2} and γ_R are the material partial safety factors used in ductility design calculations.

γ_{M0} : general partial factors for material properties of steel – 1 EN 1993-1-1:2005

γ_{M2} : partial factors for material properties of steel I tension of fracture – 1.25 EN 1993-1-1:2005

γ_R : partial factors for material properties of timber – 1.3 EN 1995-1-1:2025, Table 4.4

k_{mod} values can be found in Table 3.3.

Table 3.3: Values of k_{mod} according to EN 1995-1-1:2025 and EN 1995-1-1:2004

Service class	Load-duration class				
	Permanent action	Long term action	Medium term action	Short term action	Instantaneous action
1	0.60	0.70	0.80	0.90	1.10
2	0.60	0.70	0.80	0.90	1.10

3.5 Ductile design with GiR

The ductile design of glued-in rod connections aims to ensure that the structural behavior of timber connections is governed by **ductile failure rather than brittle failure**. This design approach focuses on promoting yielding of the steel rod instead of sudden failure of the adhesive or surrounding timber. EN 1995-1-1:2025 provides definition of the ductile design with two different methods.

The **simplified method** is based on predefined assumptions and limiting criteria ($k_{mod} = 1.1$, rod diameter and strength class and embedment depth) allowing the connection to be classified as sufficiently ductile without explicitly modeling its full load–deformation behavior. It is intended for practical design and standard applications.

In contrast, the **rigorous method** requires actual steel properties (95th percentile of the tensile resistance of the rod) for an explicit evaluation of the tensile loaded glued-in rod connection, taking into account the used adhesive and timber, and comparing ductility directly from the calculated characteristic withdrawal resistance. This approach is intended for critical or non-standard applications where a more accurate assessment is needed.

The relevant verifications for both simplified and rigorous methods are given in Section 3.7. Ductile behavior in glued-in rod connections is particularly **important for tension-loaded connections**, as it allows for gradual load transfer and provides a more reliable and controlled failure mechanism. An important requirement for ductile design of a connection is the presence of a **not-bonded length of at least 5-times the rod diameter in the yielding zone**. The Hilti GiR system includes a **debonding sleeve** for this purpose (see Section 2.1.3).

3.6 Verifications in the timber member

The following verifications must be carried out in the timber member. As a result, the decisive resistance is the one with the highest utilization among the ones listed in the previous verifications. Detailed calculations are shown in the worked-out examples in Section 5.

- **Timber member failure** ($F_{t,d} \leq F_{t,0,Rd}$)
 $F_{t,d}$: design tension load of the connection
 $F_{t,0,Rd}$: design tensile resistance of the timber member

- **Block shear failure** ($F_{t,d} \leq F_{block,Rd}$)
 $F_{t,d}$: design tension load of the connection
 $F_{block,Rd}$: design block shear capacity

These detailed verifications can be found in the design example no. 1.

- **Transverse pressure-loaded steel rod (unreinforced)** ($F_{c,90,d} \leq F_{c,90,Rd}$) if this condition is not fulfilled, reinforcement is required.
- $F_{c,90,d}$: design compression load perpendicular to the grain
 $F_{c,90,Rd}$: design compression resistance perpendicular to the grain
- **Transverse pressure loaded steel rod (reinforced)** (area-1) (area-2) ($F_{c,90,d} \leq F_{1-2,90,Rd}$)
 $F_{c,90,d}$: design compression load perpendicular to the grain
 $F_{1-2,90,Rd}$: area 1 and area 2 design compression load perpendicular to the grain

These verifications can be found in design example no. 3.

3.7 Verifications in the steel member

The following verifications must be carried out in the steel member:

- **Tension loaded steel rod** ($F_{t,d} \leq R_{ax,d}$)
 $F_{t,d}$: design tension load of the connection
 $R_{ax,d}$: design load carrying capacity of an axially loaded connection
- **Compression loaded steel rod** ($F_{c,d} \leq F_{ax,Rd}$)
 $F_{c,d}$: design compression force per threaded rod
 $F_{ax,Rd}$: design value of axial withdrawal capacity of a threaded rod
- **Shear loaded steel rod** ($F_{V,d} \leq F_{D,d}$)
 $F_{V,d}$: design shear force per threaded rod
 $F_{D,d}$: design laterally loaded resistance per threaded rod
- **Combination of shear and tension/compression loads**
 $(F_{ax,d}/F_{ax,Rd})^p + (F_{V,d}/F_{D,d})^p \leq 1$

These detailed verifications can be found in design example no. 2.

- **Ductility (simplified method)** ($\frac{F_{w,d}}{F_{t,d}} \geq 1.5$)
 $F_{w,d}$: design withdrawal resistance
 $F_{t,d}$: design tensile load of the connection
- **Ductility (rigorous method)** ($F_{t,0.95} \leq F_{w,k}$)
 $F_{t,0.95}$: 95th percentile of the tensile resistance of the rod
 $F_{w,k}$: characteristic withdrawal resistance

This detailed verification can be found in design example no. 1.

3.8 Verification of mortar

The following verification must be carried out for the mortar used in the connection:

- **Adhesive joint withdrawal** ($F_{t,d} \leq F_{w,Rd}$)

$F_{t,d}$: design tensile load of the connection

$F_{w,Rd}$: design withdrawal resistance of the joint

This detailed verification can be found in design example no. 1.

4. Software

Software tools play a crucial role in modern timber design by enabling accurate, efficient, and consistent assessment of complex structural connections. The design of glued-in rod (GiR) connections and reinforcement applications involves multiple interacting parameters, such as timber properties, adhesive behavior, rod geometry and load transfer mechanisms, which are difficult to evaluate reliably using manual calculations alone.

Hilti design software's GiR module provides tension connection, transverse compression reinforcement and moment-loaded connection application design by implementing the relevant code-based verifications, allowing engineers to evaluate design and reinforcement applications with greater confidence and efficiency.

The design module features a user-friendly interface supported by detailed drawings and three-dimensional visualizations, helping to make the design process intuitive. It helps to minimize necessary inputs while allowing for full design flexibility of the connector. This cloud-based solution can be accessed through any web browser on a PC, Mac, tablet, or smartphone via the **PROFIS Engineering suite** starting page. No installation or updates are required.

Please follow the link above and click on the **Mass Timber** icon (Fig. 4.1) to access Hilti GiR module.

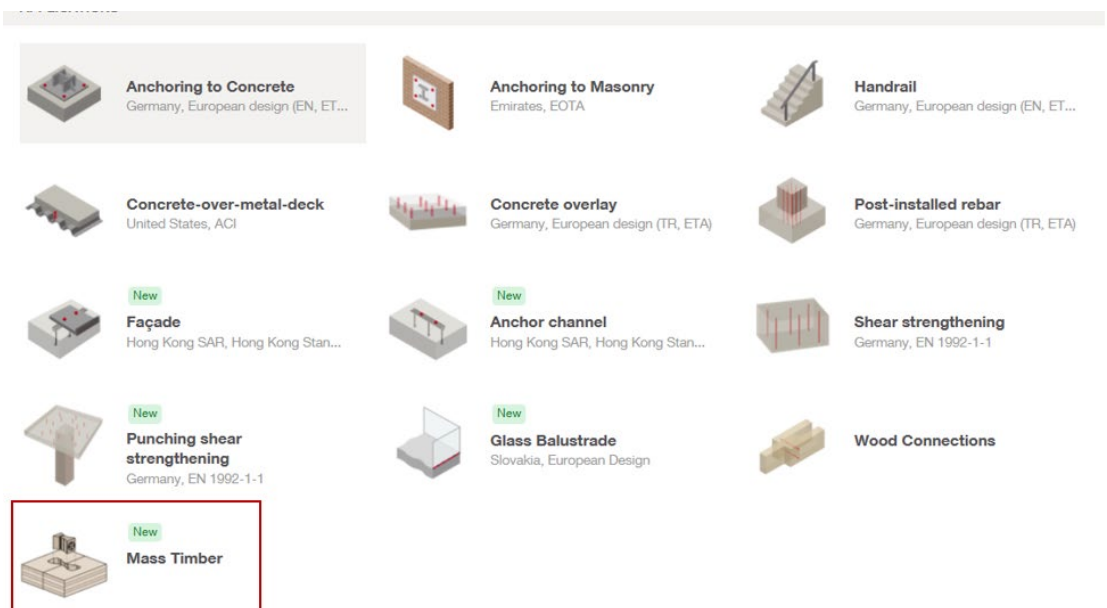


Fig. 4.1: Hilti PROFIS engineering software Mass Timber icon for the GiR module

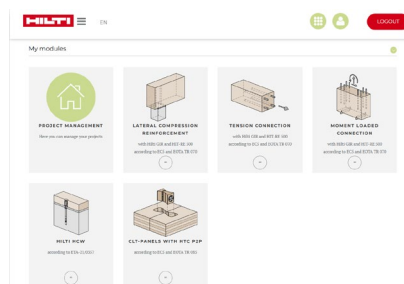
The design module supports static and quasi-static design. It also generates a comprehensive design report referencing the state-of-the-art design method and approval documents. Whether your project is small or large, this tool helps you to achieve efficient results.

To get you started, a streamlined design flow is given below, offering an overview for new or less experienced users on how to use the software module and its main inputs (Fig. 4.2).

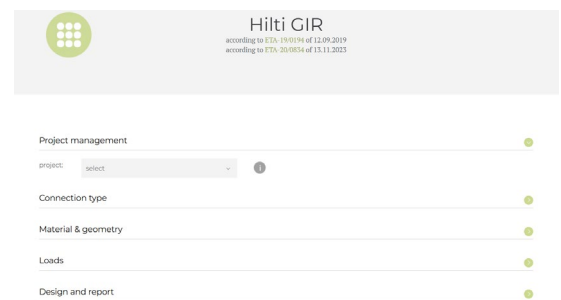
1. **Select the Hilti GiR design module:** an editable interface will open, divided into multiple sections guiding you through the overall design process (Fig. 4.2a).
2. **Project management:** create a new project or refer to an existing one. For each project, multiple connector “positions” can be defined, each being a separate design case. This feature allows the saving of multiple design configurations for a single project. Projects and

positions can be retrieved from the Project Management tile's main interface (Fig. 4.2b).

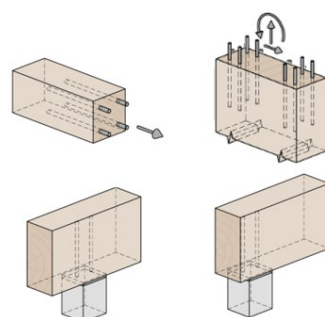
3. **Connection type:** define your application by selecting the relevant one (Fig. 4.2c).
4. **Material & geometry:** define the service class (based on EN 1995-1-1 definition), then detail the timber component, width and height. For the timber component, you can define it by selecting a specific engineered timber product and strength class from the predefined library. A connector's diameter and steel grade, adhesive, drilling diameter, embedment depth, not-bonded length, distance from the edge of the timber member and spacing between connectors is determined by the user (Fig. 4.2d).
5. **Loads:** input the magnitudes of the acting loads and define the load-duration class (Fig. 4.2e).
6. **Design and report:** this section displays the main design output, visualizing the verifications for the individual failure modes. It also allows generating a comprehensive design report detailing all the design calculations and verifications performed by the software. The report is generated in PDF format, making it easy to export and save (Fig. 4.2f). It does not replace the project-specific verification required from the responsible structural engineer.



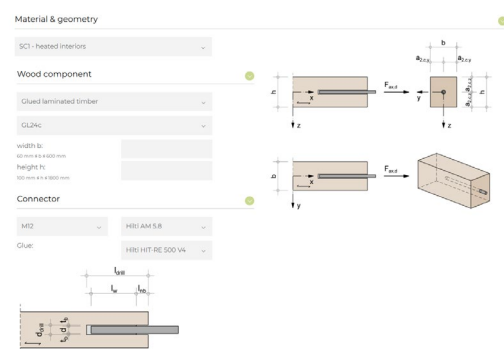
a) Step 1 – Select the Hilti GiR design module



b) Step 2 – Project management



c) Step 3 – Connection type



d) Step 4 – Material & geometry

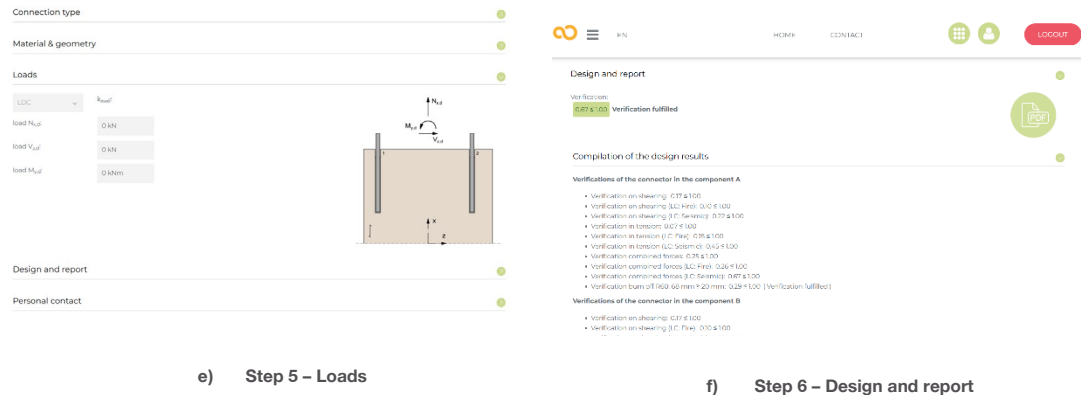


Fig. 4.2: Hilti software for GiR design steps

The use of the GiR module is free of charge: <https://profisengineering.hilti.com/>

Remarks

Any and all information and data contained in the software concern solely the use of Hilti products and are based on the principles, formulas, and security regulations in accordance with Hilti technical directions and operating, mounting and assembly instructions, etc., that must be strictly complied with by the user. The Hilti PROFIS Engineering software is a design-assistance tool. All results of the calculations carried out by means of the software depend on the input data defined by user. Therefore, the user bears the sole responsibility for the absence of errors, as well as the completeness and the relevance of the data the user entered into the software. The responsible structural engineer must verify all calculations and determine suitability for the specific project.

5. Design examples

In this chapter, different glued-in rod application design examples are presented. Each verification step is explained for different members within the connection. In the following, design examples are provided covering the following cases:

1. Tensile joint width loading parallel to the grain + ductility check
2. Moment-loaded column connection
3. Transverse compression reinforcement

5.1 Design Example no. 1: Tensile joint width loading parallel to the grain

Description of the application: Tensile-loaded connection, 2x2 diameter M20 Hilti 4.6 AM steel-grade threaded rods are installed in a glue-laminated timber member using Hilti HIT-RE 500 V4 (Fig. 5.1).

Geometry:

Timber member: $b \times h = 240 \times 240 \text{ mm}$

Edge distance: $a_{2,c,y}; a_{2,c,z} = 50 \text{ mm}$

Spacing: $a_{2,y}; a_{2,z} = 140 \text{ mm}$

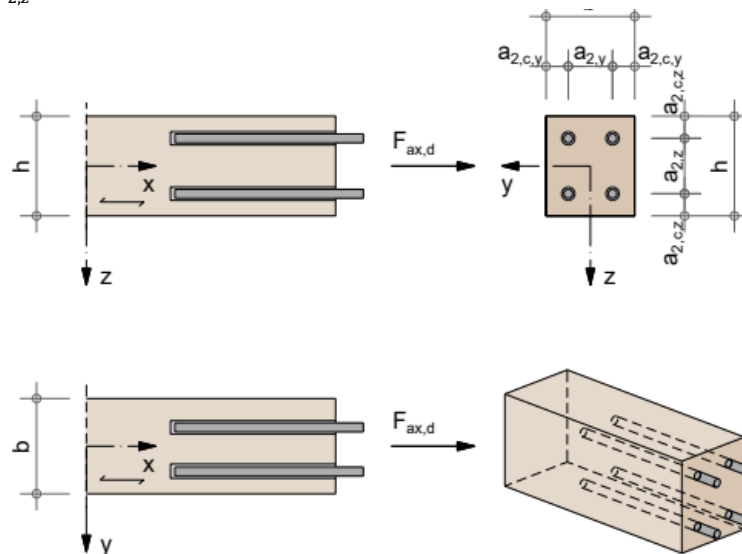


Fig. 5.1: Details of the connection

Loading:

Design tension force: 145 kN

Load duration class: Short, $k_{mod} = 0.9$

Service class: Covered open structures, 2

Material property of the timber:

Engineered timber product: Glue-laminated timber

Strength class: GL24c

Characteristic tensile strength: $f_{t,0,k} = 17 \text{ N/mm}^2$

Characteristic shear strength: $f_{v,k} = 3.5 \text{ N/mm}^2$
 Failure strain of the timber parallel to the grain: $\varepsilon_{u,tim} = 0.0022$

Connector: (Fig. 5.2)

Diameter: 20 mm
 Layout: $n_y = 2; n_z = 2$
 Embedment depth: $l_w = 600 \text{ mm}$
 Threaded rod steel grade: 4.6
 Ultimate strength of the threaded rod: $f_{uk} = 400 \text{ N/mm}^2$
 Yielding strength of the threaded rod: $f_{yk} = 240 \text{ N/mm}^2$
 Young module: $E_s = 210,000 \text{ N/mm}^2$
 Cross section of the threaded rod: $A_s = 245 \text{ mm}^2$

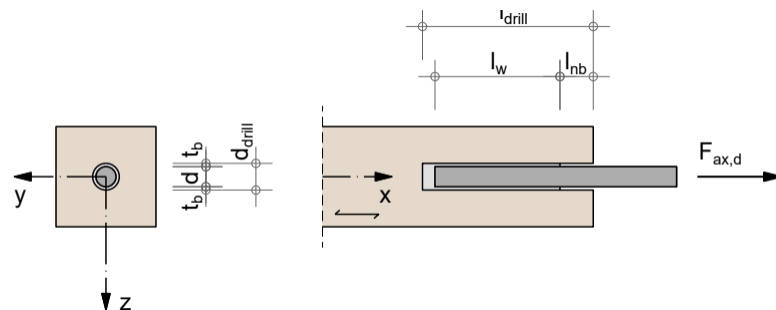


Fig. 5.2: Details of the connection

Installation method and parameters for the connector:

Installation method: Direct filling
 Drilling diameter: 22 mm
 Not-bonded length: $l_{nb} = 0 \text{ mm}$
 Drilling length: $l_{drill} = 600 \text{ mm}$
 Annular gap: $t_b = 1 \text{ mm}$

Verification of the minimum distances in the timber:

$a_{2,c,y} = 50 \text{ mm} \geq a_{2,c,min} = 2.5d = 50 \text{ mm}$ EOTA TR 070, Table 4.1

$a_{2,y} = 140 \text{ mm} \geq a_{2,min} = 5d = 100 \text{ mm}$ EOTA TR 070, Table 4.1

$a_{2,c,z} = 50 \text{ mm} \geq a_{2,c,min} = 2.5d = 50 \text{ mm}$ EOTA TR 070, Table 4.1

$a_{2,z} = 140 \text{ mm} \geq a_{2,min} = 5d = 100 \text{ mm}$ EOTA TR 070, Table 4.1

verifications fulfilled

Verification of steel resistance:

$$f_{uk} = 400 \text{ N/mm}^2 \quad f_{yk} = 240 \text{ N/mm}^2 \quad A_s = A_{ef} = 245 \text{ mm}^2$$

$$F_{ax,Rd} = f_{yd} \cdot A_{ef} = A_{ef} \cdot \frac{f_{yk}}{\gamma_M} = 245 \cdot \frac{240}{1.3} \cdot 10^{-3} = 45.23 \text{ kN}$$

EOTA TR 070, Eq. (4.1 - 4.2)

$$R_{ax,d} = F_{ax,Rd} \cdot n_{ef} = n^{0.9} \cdot F_{ax,Rd} = 4^{0.9} \cdot 45.23 = 157.5 \text{ kN}$$

EN 1995-1-1:2004, Eq. (8.41)

$$\frac{F_{t,d}}{R_{ax,d}} = \frac{145.0}{157.5} = 0.92 \leq 1.0$$

verification fulfilled ✓

Verification of adhesive joint strength:

$$l_w = l_a = 600 \text{ mm}$$

$$l_{a,min} = \max(0.5d^2; 10d; 100 \text{ mm})$$

EOTA TR 070, Eq. (4.4) ETA-20/0834, Table 4

$$l_{a,min} = \max(200; 200; 100) = 200 \text{ mm} \leq l_w = 600 \text{ mm}$$

$$l_{w,max} = \min(40d; 1000 \text{ mm})$$

EN 1995-1-1:2025, Eq. (11.87) ETA-20/0834, Table 4

$$l_{w,max} = \min(800; 1000) = 800 \text{ mm} \geq l_w = 600 \text{ mm}$$

$$f_{vr,k} = 3.80 - 0.0015 \cdot l_a = 3.80 - 0.0015 \cdot 600 = 2.9 \text{ N/mm}^2$$

ETA-20/0834, Table 4

$$f_{vr,d} = k_{mod} \cdot \frac{f_{vr,k}}{\gamma_m} = 0.9 \cdot \frac{2.9}{1.30} = 2.01 \text{ N/mm}^2$$

EOTA TR 070, Eq. (4.3)

Adhesive joint load-bearing capacity per adhesive joint:

$$F_{w,d} = \min \left\{ \begin{array}{l} \pi \cdot d \cdot l_a \cdot f_{vr,d} \\ \frac{k_{mod}}{\gamma_m} \cdot E_s \cdot A_s \cdot \varepsilon_{u,tim} \end{array} \right.$$

EN 1995-1-1:2025, Eq. (11.85)

$$F_{w,d} = \min \left\{ \begin{array}{l} \pi \cdot 20 \cdot 600 \cdot 2.01 \cdot 10^{-3} \\ \frac{0.9}{1.3} \cdot 210,000 \cdot 245 \cdot 0.0022 \cdot 10^{-3} \end{array} \right.$$

$$F_{w,d} = 75.78 \text{ kN}$$

Design withdrawal resistance of the joint:

$$F_{w,Rd} = F_{w,d} \cdot n_{ef} = n^{0.9} \cdot F_{w,d} = 4^{0.9} \cdot 75.78 = 263.88 \text{ kN}$$

EN 1995-1-1:2004, Eq. (8.41)

$$\frac{F_{t,d}}{F_{w,Rd}} = \frac{145.0}{263.88} = 0.55 \leq 1.0$$

verification fulfilled ✓

Verification of the minimum spacing and distance for the timber member: (Fig. 5.3)

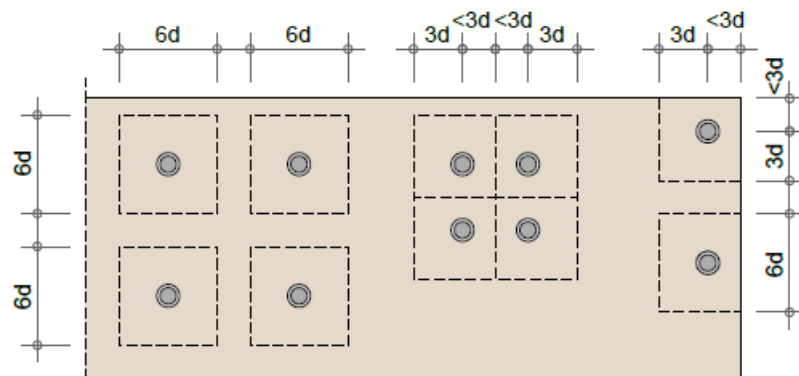


Fig. 5.3: Effective timber areas for bonded-in rods parallel to grain according to EN 1995-1-1:2025

$$a_{2,c,y} = 50 \text{ mm} < 3d = 60 \text{ mm} \quad e_{2,c,y} = 50 \text{ mm} \quad \text{EN 1995-1-1:2025, Figure 11.38}$$

$$a_{2,y} = 140 \text{ mm} \geq 6d = 120 \text{ mm} \quad e_{2,y} = 60 \text{ mm} \quad \text{EN 1995-1-1:2025, Figure 11.38}$$

$$a_{2,c,z} = 50 \text{ mm} < 3d = 60 \text{ mm} \quad e_{2,c,z} = 50 \text{ mm} \quad \text{EN 1995-1-1:2025, Figure 11.38}$$

$$a_{2,z} = 140 \text{ mm} \geq 6d = 120 \text{ mm} \quad e_{2,z} = 60 \text{ mm} \quad \text{EN 1995-1-1:2025, Figure 11.38}$$

Tensile load-bearing capacity in net cross-section:

$$A_{ef} = \frac{n_{ef}}{n} \cdot \left[n \cdot (e_{2,c,y} + e_{2,y}) \cdot (e_{2,c,z} + e_{2,z}) - n \cdot \pi \cdot \left(\frac{d_{drill}}{2} \right)^2 \right] \quad \text{EN 1995-1-1:2025, 11.10.5.2}$$

$$A_{ef} = \frac{3.48}{4} \cdot \left[4 \cdot (50 + 60) \cdot (50 + 60) - 4 \cdot \pi \cdot \left(\frac{22}{2} \right)^2 \right] = 40785 \text{ mm}^2$$

$$F_{t,0,Rd} = k_{mod} \cdot \frac{f_{t,0,k} \cdot A_{ef}}{\gamma_m} \quad \text{EN 1995-1-1:2025, Eq. (11.92)}$$

$$F_{t,0,Rk} = f_{t,0,k} \cdot A_{ef} = 17 \cdot 40785 \cdot 10^{-3} = 693.35 \text{ kN}$$

$$F_{t,0,Rd} = k_{mod} \cdot \frac{F_{t,0,Rk}}{\gamma_m} = 0.9 \cdot \frac{693.35}{1.30} = 480.01 \text{ N/mm}^2$$

$$\frac{F_{t,d}}{F_{t,0,Rd}} = \frac{145.0}{480.01} = 0.30 \leq 1.0$$

verification fulfilled ✓

Verification of block shear capacity: (Fig. 5.4)

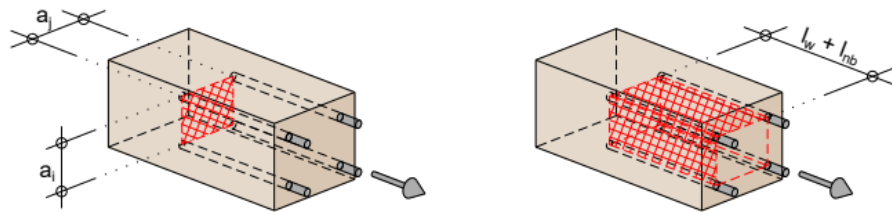


Fig. 5.4: Block area details in the timber member

$$A_{net,t} = \sum a_i \cdot \sum a_j \quad \text{EOTA TR 070, Fig. (4.3)}$$

$$A_{net,v} = 2 \cdot (\sum a_i + \sum a_j) \cdot (l_w + l_{nb}) \quad \text{EOTA TR 070, Fig. (4.3)}$$

$$A_{net,t} = \sum a_i \cdot \sum a_j = \sum 140 \cdot \sum 140 = 19,600 \text{ mm}^2$$

$$A_{net,v} = 2 \cdot (\sum a_i + \sum a_j) \cdot (l_w + l_{nb}) = 2 \cdot (140 + 140) \cdot 600 = 336,000 \text{ mm}^2$$

$$F_{block,Rk} = \max \begin{cases} 1.5 \cdot f_{t,0,k} \cdot A_{net,t} = 1.5 \cdot 17 \cdot 19,600 \cdot 10^{-3} \\ 0.7 \cdot f_{v,k} \cdot A_{net,v} = 0.7 \cdot 3.5 \cdot 336,000 \cdot 10^{-3} \end{cases} \quad \text{EN 1995-1-1, (A.1)}$$

$$F_{block,Rk} = 823.2 \text{ kN}$$

$$F_{block,Rd} = k_{mod} \cdot \frac{F_{block,Rk}}{\gamma_M} \quad \text{EN 1995-1-1, Eq. (2.14)}$$

$$F_{block,Rd} = 0.9 \cdot \frac{823.2}{1.3} = 569.9 \text{ kN}$$

$$\frac{F_{t,d}}{F_{block,Rd}} = \frac{145.0}{569.9} = 0.25 \leq 1.0$$

verification fulfilled ✓

Summary of verifications

Verifications in the timber member

Tension load bearing capacity:

$$\frac{F_{t,d}}{F_{t,0,Rd}} = \frac{145.0}{480.01} = 0.30 \leq 1.0$$

Block shear capacity:

$$\frac{F_{t,d}}{F_{t,Rd}} = \frac{145.0}{569.9} = 0.25 \leq 1.0$$

Verifications on the threaded rod

Tension loaded steel rod:

$$\frac{F_{t,d}}{F_{t,Rd}} = \frac{145.0}{157.5} = 0.92 \leq 1.0$$

Verifications on the adhesive

Adhesive joint withdrawal:

$$\frac{F_{t,d}}{F_{w,Rd}} = \frac{145.0}{263.88} = 0.55 \leq 1.0$$

In addition to the verifications described above, the **ductility of the connection can also be assessed**. The ductility verification is performed using a simplified method. To achieve a ductile connection, the **load duration class** (k_{mod}) **must be taken as instantaneous (1.1)**. A **not-bonded length equal to 5 diameters** must be considered during the installation phase, and **bypass filling** must be used as the installation method. As highlighted in Section 3.5, Hilti **debonding sleeve** may to be used to achieve a ductile design. This means that the installation depth is increased by $5 \cdot 20 = 100 \text{ mm}$ and the drilling diameter must be increased from 22 mm to 24 mm. The increase of the annular gap from 1 to 2 mm requires the use of the **centering ring** according to the IFU as explained in Section 2.1.

Verification of ductility – Simplified method:

$$F_{t,d} = \min \left\{ \frac{A_s \cdot f_{yk}}{\gamma_{M0}}; \frac{0.9 \cdot A_s \cdot f_{uk}}{\gamma_{M2}} \right\} \quad \text{EN 1995-1-1:2025, Eq. (11.83)}$$

$$F_{t,d} = \min \left\{ \frac{245 \cdot 240}{1}; \frac{0.9 \cdot 245 \cdot 400}{1.25} \right\} = 58800 \text{ N} = 58.8 \text{ kN}$$

Steel tensile load-bearing capacity of the connection:

$$F_{t,Rd} = n_{ef} \cdot F_{t,d} = n^{0.9} \cdot F_{t,d} \quad \text{EN 1995-1-1:2004, Eq. (8.41)}$$

$$F_{t,Rd} = 4^{0.9} \cdot 58.8 = 204.75 \text{ kN} > 145 \text{ kN} \quad \text{verification fulfilled } \checkmark$$

$$F_{w,0,k} = \min \left\{ \frac{\pi \cdot d \cdot l_{w,ef} \cdot f_{w,k}}{E_s \cdot A_s \cdot \varepsilon_{u,tim}} \right\} \quad \text{EN 1995-1-1:2025, Eq. (11.85)}$$

$$F_{w,0,k} = \min \left\{ \frac{\pi \cdot 20 \cdot 600 \cdot 2.9}{210,000 \cdot 245 \cdot 0.0022} = 109,320 \text{ N} = 109.32 \text{ kN} \right.$$

$$F_{w,d} = k_{mod} \cdot \frac{F_{w,0,k}}{\gamma_R} \quad \text{EN 1995-1-1:2025, Eq. (11.84)}$$

$$F_{w,d} = 1.1 \cdot \frac{109.32}{1.3} = 92.5 \text{ kN}$$

$$F_{w,Rd} = F_{wd} \cdot n_{ef} = n^{0.9} \cdot F_{wd} = 4^{0.9} \cdot 92.5 = 322.10 \text{ kN} \quad \text{EN 1995-1-1:2004, Eq. (8.41)}$$

$$\frac{F_{w,Rd}}{F_{t,Rd}} = \frac{322.10}{204.75} = 1.57 \geq 1.5 \quad \text{verification fulfilled, connection is considered ductile} \quad \checkmark$$

According to EN 1995-1-1:2025, Eq. (11.91) the ratio between the design withdrawal resistance ($F_{w,Rd}$) and the design tensile load of the connection ($F_{t,Rd}$) **must be equal or greater than 1.5** for the tensile loaded connection to be considered ductile in the simplified method.

In addition to simplified method, there is rigorous design method which also verifies whether the connection is ductile or not. The same inputs in design example no. 1. will be used for verification.

Verification of ductility – Rigorous method:

$$F_{t,0.95} \leq F_{w,k} \quad \text{EN 1995-1-1:2025, Eq. (11.89)}$$

$$F_{t,0.95} = A_s \cdot f_{y,0.95} \quad \text{EN 1995-1-1:2025, Eq. (11.91)}$$

$$F_{t,0.95} = 245 \cdot 228 = 55.86 \text{ kN}$$

$$F_{w,0,k} = \min \left\{ \frac{\pi \cdot 20 \cdot 600 \cdot 2.9}{210,000 \cdot 245 \cdot 0.0022} = 109,320 \text{ N} = 109.32 \text{ kN} \right. \quad \text{EN 1995-1-1:2025, Eq. (11.85)}$$

$$F_{t,0.95} \leq F_{w,k} = 55.86 \leq 109.32 \quad \text{verification fulfilled, connection is considered ductile} \quad \checkmark$$

5.2 Design Example no. 2: Moment-loaded connection

Description of the application: Moment-, tension- and shear-loaded connection, 1x2 M24 diameter Hilti 8.8 AM steel grade threaded rods are installed in a glue-laminated timber member using Hilti HIT-RE 500 V4 (Fig. 5.5).

Geometry:

Timber member: $b \times h = 450 \times 600 \text{ mm}$

Edge distance: $a_{e1,z} = 60 \text{ mm}$; $a_{e2,z} = 96 \text{ mm}$; $a_{2,c,y} = 225 \text{ mm}$

Spacing: $a_z = 444 \text{ mm}$

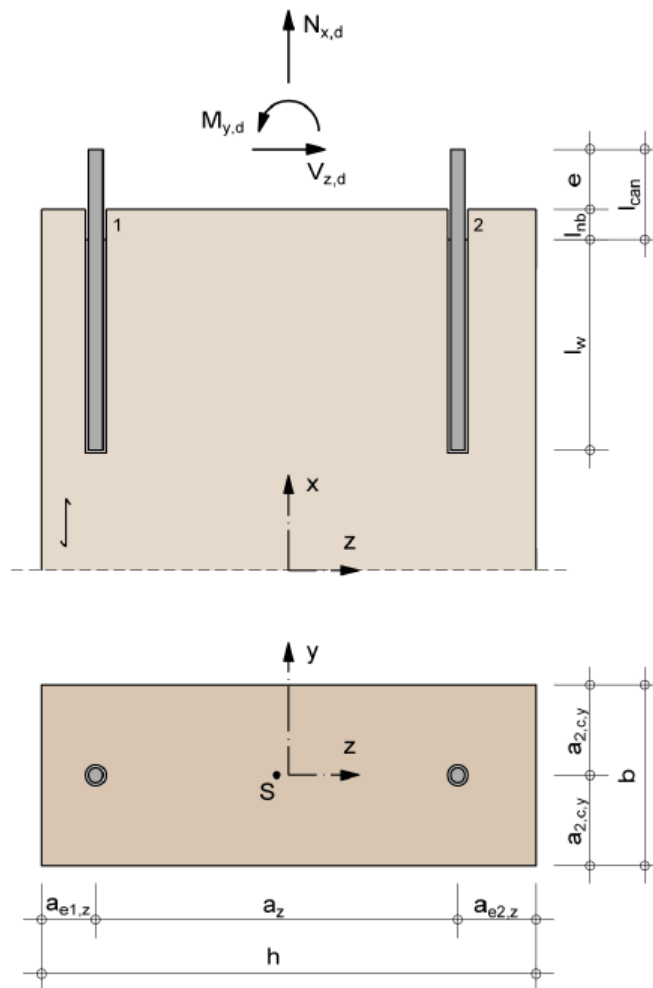


Fig. 5.5: Details of the connection

Loading:

Tension force: $N_{x,d} = 15 \text{ kN}$

Shear force: $V_{z,d} = 6.2 \text{ kN}$

Moment: $M_{y,d} = 5.13 \text{ kNm}$

Load duration class: Short, $k_{mod} = 0.9$

Service class: Heated interiors, 1

Material property of the timber:

Engineered timber product: Glue-laminated timber

Strength class: GL24c

Characteristic tensile strength: $f_{t,0,k} = 17 \text{ N/mm}^2$

Characteristic shear strength: $f_{v,k} = 3.5 \text{ N/mm}^2$

Failure strain of the timber parallel to the grain: $\epsilon_{u,tim} = 0.0022$

Connector: (Fig. 5.6)

Diameter: 24 mm

Layout: $n_y = 1$; $n_z = 2$

Embedment depth: $l_w = 625 \text{ mm}$
 Threaded rod steel grade: 8.8
 Ultimate strength of the threaded rod: $f_{uk} = 800 \text{ N/mm}^2$
 Yielding strength of the threaded rod: $f_{yk} = 640 \text{ N/mm}^2$
 Young module: $E_s = 210,000 \text{ N/mm}^2$
 Cross section of the threaded rod: $A_s = 353 \text{ mm}^2$

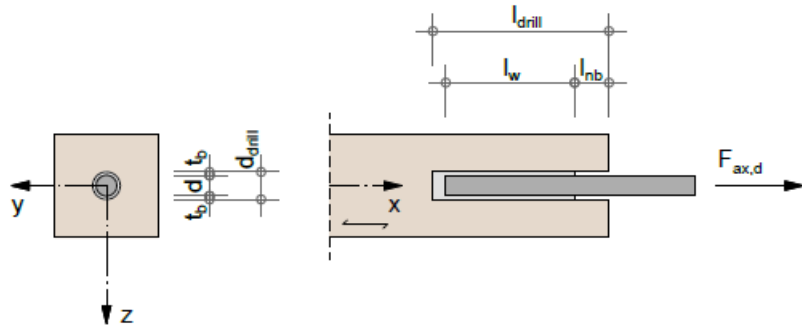


Fig. 5.6: Details of the connection

Installation method and parameters for the connector:

Installation method: Direct filling
 Drilling diameter: 26 mm
 Not-bonded length: $l_{nb} = 0 \text{ mm}$
 Drilling length: $l_{drill} = 625 \text{ mm}$
 Annular gap: $t_b = 1 \text{ mm}$

Design loads per threaded rod:

Center of gravity and distances between fastener groups:

$$CG_z : \frac{h}{2} = 300 \text{ mm}$$

$$CG_y : \frac{b}{2} = 225 \text{ mm}$$

$$CF_z = \frac{\sum_{i=1}^n z_i}{n} = \frac{1 \cdot (a_{e1,z}) + 1 \cdot (a_{e1,z} + a_z)}{n} = \frac{1 \cdot (60) + 1 \cdot (60 + 444)}{2} = 282 \text{ mm}$$

$$CF_y = \frac{\sum_{i=1}^n y_i}{n} = \frac{1 \cdot (a_{2,c,y}) + 1 \cdot (a_{2,c,y} + a_{2,y})}{n} = \frac{1 \cdot (225) + 1 \cdot (225 + 0)}{2} = 225 \text{ mm}$$

$$S_z = CF_z - CG_z = 282 - 300 = -18 \text{ mm}$$

$$S_y = CF_y - CG_y = 225 - 225 = 0 \text{ mm}$$

$$z_1 = \frac{-a_z}{2} = -222 \text{ mm}$$

$$z_2 = \frac{a_z}{2} = 222 \text{ mm}$$

Polar moment of inertia:

$$I_p = n_y \cdot (|z_1|^2 + |z_2|^2 + |z_3|^2 + |z_4|^2 + \dots + |z_n|^2) = 1 \cdot (-222^2) + (222^2) = 98,568 \text{ mm}^2$$

Maximum tensile and shear force per threaded rod:

$$F_{max,ax,d} = \max \left\{ \begin{aligned} &\frac{N_{x,d}}{n_y \cdot n_z} - \frac{N_{x,d} \cdot S_z}{I_p} \cdot z_1 + \frac{M_{y,d}}{I_p} \cdot z_1 \\ &\frac{N_{x,d}}{n_y \cdot n_z} - \frac{N_{x,d} \cdot S_z}{I_p} \cdot z_2 + \frac{M_{y,d}}{I_p} \cdot z_2 \end{aligned} \right.$$

$$F_{max,ax,d} = \max \left\{ \begin{aligned} &\frac{15}{2} - \frac{15 \cdot (-18)}{98,568} \cdot (-222) + \frac{5.13}{98,568} \cdot (-222) \cdot 10^3 = -4.66 \text{ kN} \\ &\frac{15}{2} - \frac{15 \cdot (-18)}{98,568} \cdot 222 + \frac{5.13}{98,568} \cdot 222 \cdot 10^3 = 19.66 \text{ kN} \end{aligned} \right.$$

$$F_{max,ax,d} = 19.66 \text{ kN}$$

$$F_{v,d} = \frac{V_{z,d}}{n_y \cdot n_z} = \frac{6.2}{2} = 3.1 \text{ kN}$$

Verification of the minimum distances in the timber member:

$$a_{2,c,y} = 225 \text{ mm} \geq a_{2,c,min} = 2.5d = 60 \text{ mm}$$

EOTA TR 070, Table 4.1

$$a_{e1,z} = 60 \text{ mm} \geq a_{2,c,min} = 2.5d = 60 \text{ mm}$$

EOTA TR 070, Table 4.1

$$a_{e2,z} = 96 \text{ mm} \geq a_{2,c,min} = 4d = 96 \text{ mm}$$

EOTA TR 070, Table 4.2

Verification of steel resistance:

$$f_{uk} = 800 \text{ N/mm}^2 \quad f_{yk} = 640 \text{ N/mm}^2 \quad A_s = A_{ef} = 353 \text{ mm}^2$$

$$F_{ax,Rd} = f_{yd} \cdot A_{ef} = A_{ef} \cdot \frac{f_{yk}}{\gamma_M} = 353 \cdot \frac{640}{1.3} \cdot 10^{-3} = 173.78 \text{ kN}$$

EOTA TR 070, Eq. (4.1 - 4.2)

$$R_{ax,d} = \frac{n_{ef}}{n_y} \cdot F_{ax,Rd} = \frac{n^{0.9}}{n_y} \cdot F_{ax,Rd} = \frac{1^{0.9}}{1} \cdot 173.78 = 173.78 \text{ kN}$$

EN 1995-1-1:2004, Eq (8.41)

Maximum tensile stress per threaded rod:

$$F_{ax,Rd} = F_{max,ax,d} = 19.66 \text{ kN}$$

$$\frac{F_{max,ax,d}}{R_{ax,d}} = \frac{19.66}{173.78} = 0.11 \leq 1.0$$

verification fulfilled

Verification of adhesive joint strength:

$$l_w = l_a = 625 \text{ mm}$$

$$l_{a,min} = \max(0.5d^2; 10d; 100 \text{ mm})$$

EOTA TR 070, Eq. (4.4) ETA-20/0834, Table 4

$$l_{a,min} = \max(288; 240; 100) = 200 \text{ mm} \leq l_w = 625 \text{ mm}$$

$$l_{w,max} = \min(40d; 1000 \text{ mm})$$

EN 1995-1-1:2025, Eq. (11.87) ETA-20/0834, Table 4

$$l_{w,max} = \min(960; 1000) = 960 \text{ mm} \geq l_w = 625 \text{ mm}$$

$$f_{vr,k} = 3.80 - 0.0015 \cdot l_a = 3.80 - 0.0015 \cdot 625 = 2.86 \text{ N/mm}^2$$

ETA-20/0834, Table 4

$$f_{vr,d} = k_{mod} \cdot \frac{f_{vr,k}}{\gamma_m} = 0.9 \cdot \frac{2.86}{1.30} = 1.98 \text{ N/mm}^2$$

EOTA TR 070, Eq. (4.3)

Adhesive joint load-bearing capacity per adhesive joint:

$$F_{w,d} = \min \left\{ \begin{array}{l} \pi \cdot d \cdot l_a \cdot f_{vr,d} \\ \frac{k_{mod}}{\gamma_m} \cdot E_s \cdot A_s \cdot \epsilon_{u,tim} \end{array} \right. \quad \text{EN 1995-1-1:2025, Eq. (11.85)}$$

$$F_{w,d} = \min \left\{ \begin{array}{l} \pi \cdot 24 \cdot 625 \cdot 1.98 \cdot 10^{-3} \\ \frac{0.9}{1.3} \cdot 210000 \cdot 353 \cdot 0.0022 \cdot 10^{-3} \end{array} \right.$$

$$F_{w,d} = 93.31 \text{ kN}$$

Design withdrawal resistance of the joint:

$$F_{w,Rd} = \frac{n_{ef}}{n_y} \cdot F_{w,d} = \frac{n^{0.9}}{n_y} \cdot F_{w,d} = \frac{1^{0.9}}{1} \cdot 93.31 = 93.31 \text{ kN} \quad \text{EN 1995-1-1:2004, Eq. (8.41)}$$

$$\frac{F_{max,ax,d}}{F_{w,Rd}} = \frac{93.31}{173.78} = 0.21 \leq 1.0$$

verification fulfilled ✓

Verification of timber strength:

Verification of the minimum spacing and distance for the timber member: (Fig. 5.7)

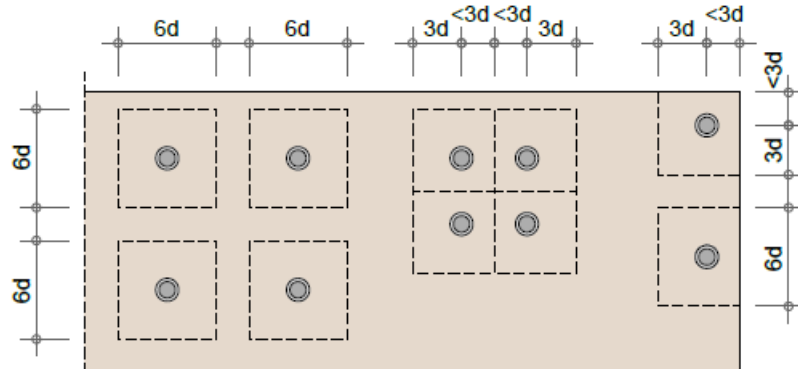


Fig. 5.7: Effective timber areas for bonded-in rods parallel to grain according to EN 1995-1-1:2025

$$a_{2,c,y} = 225 \text{ mm} \geq 3d = 72 \text{ mm}$$

$$e_{2,c,y} = 72 \text{ mm}$$

EN 1995-1-1:2025, Figure 11.38

$$a_{e1,z} = 60 \text{ mm} < 3d = 72 \text{ mm}$$

$$e_{e1,z} = 60 \text{ mm}$$

EN 1995-1-1:2025, Figure 11.38

$$a_{e2,z} = 96 \text{ mm} \geq 3d = 72 \text{ mm}$$

$$e_{e2,z} = 72 \text{ mm}$$

EN 1995-1-1:2025, Figure 11.38

$$a_z = 444 \text{ mm} \geq 6d = 144 \text{ mm}$$

$$e_z = 72 \text{ mm}$$

EN 1995-1-1:2025, Figure 11.38

Tensile load-bearing capacity in net cross-section:

$$A_{ef} = (2 \cdot e_{2,c,y} + (n_y - 1) \cdot 2 \cdot e_{2,y}) \cdot (e_{2,z} + e_z) - n_y \cdot \pi \cdot \left(\frac{d_{drill}}{2}\right)^2 \quad \text{EN 1995-1-1:2025, 11.10.5.2}$$

$$A_{ef} = (2 \cdot 72 + (1 - 1) \cdot 2 \cdot 0) \cdot (72 + 72) - 1 \cdot \pi \cdot \left(\frac{26}{2}\right)^2 = 20,205.07 \text{ mm}^2$$

$$F_{t,0,Rd} = k_{mod} \cdot \frac{f_{t,0,k} \cdot A_{ef}}{\gamma_M} \cdot \frac{n_y^{0.9}}{n_y} \quad \text{EN 1995-1-1:2025, Eq. (11.92)}$$

$$F_{t,0,Rk} = f_{t,0,k} \cdot A_{ef} = 17 \cdot 20,205.07 \cdot 10^{-3} = 343.48 \text{ kN}$$

$$F_{t,0,Rd} = 0.9 \cdot \frac{343.48}{1.30} \cdot \frac{1^{0.9}}{1} = 237.8 \text{ N/mm}^2$$

$$\frac{n_y \cdot F_{max,ax,d}}{F_{t,0,Rd}} \leq 1 = \frac{1 \cdot 19.66}{237.8} = 0.08 \leq 1.0 \quad \text{EN 1995-1-1:2025, 11.10.5.2(3), verification fulfilled} \quad \checkmark$$

Compression on the threaded rod:

$$l_w = l_a = 625 \text{ mm}$$

$$l_{a,min} = \max(0.5d^2; 10d; 100 \text{ mm}) \quad \text{EOTA TR 070, Eq. (4.4) ETA-20/0834, Table 4}$$

$$l_{a,min} = \max(288; 240; 100) = 200 \text{ mm} \leq l_w = 625 \text{ mm}$$

$$l_{w,max} = \min(40d; 1000 \text{ mm}) \quad \text{EN 1995-1-1:2025, Eq. (11.87) ETA-20/0834, Table 4}$$

$$l_{w,max} = \min(960; 1000) = 960 \text{ mm} \geq l_w = 625 \text{ mm}$$

$$f_{vr,k} = 3.80 - 0.0015 \cdot l_a = 3.80 - 0.0015 \cdot 625 = 2.86 \text{ N/mm}^2 \quad \text{ETA-20/0834, Table 4}$$

$$f_{vr,d} = k_{mod} \cdot \frac{f_{vr,k}}{\gamma_m} = 0.9 \cdot \frac{2.86}{1.30} = 1.98 \text{ N/mm}^2 \quad \text{EOTA TR 070, Eq. (4.3)}$$

Resistance to buckling:

$$E_s \cdot I_s = \frac{210000 \cdot A_s^2}{\pi \cdot 4} = \frac{210000 \cdot 353^2}{\pi \cdot 4} = 2,082,374,521.89 \text{ Nmm}^2 \quad \text{Z-9.1-791, Eq. (10)}$$

$$c_h = (0.19 + 0.012 \cdot d) \cdot p_k \cdot 0.5 \quad \text{Z-9.1-791, Eq. (9)}$$

$$c_h = (0.19 + 0.012 \cdot 24) \cdot 365 \cdot 0.5 = 87.24 \text{ N/mm}^2$$

$$N_{ki,k} = \sqrt{c_h \cdot E_s \cdot I_s} = \sqrt{87.24 \cdot 2,082,374,521.89 \cdot 10^{-3}} = 426.22 \text{ kN} \quad \text{Z-9.1-791, Eq. (8)}$$

$$N_{pl,k} = A_s \cdot f_{y,k} = 3.53 \cdot 640 \cdot 10^{-1} = 225.92 \text{ kN} \quad \text{Z-9.1-791, Eq. (6)}$$

$$N_{pl,d} = \frac{N_{pl,k}}{\gamma_m} = \frac{225.92}{1.1} = 205.38 \text{ kN} \quad \text{Z-9.1-791, Eq. (7)}$$

$$\lambda_k = \sqrt{\frac{N_{pl,k}}{N_{ki,k}}} = \sqrt{\frac{225.92}{426.22}} = 0.73 \quad \text{Z-9.1-791, Eq. (5)}$$

$$k = 0.5 \cdot [1 + 0.49 \cdot (\lambda_k - 0.2) + \lambda_k^2] = 0.5 \cdot [1 + 0.49 \cdot (0.73 - 0.2) + 0.73^2] = 0.896 \quad \text{Z-9.1-791, Eq. (4)}$$

$$k_c = \frac{1}{k + \sqrt{k^2 - \lambda_k^2}} = \frac{1}{0.896 + \sqrt{0.896^2 - 0.73^2}} = 0.706 \quad \text{Z-9.1-791, Eq. (3)}$$

$$F_{ax,Rd} = \min \begin{cases} \text{Adhesive joint strength} \\ \text{Expansion capacity of the timber} \\ \text{Buckling resistance} \end{cases} \quad \text{EN 1995-1-1:2025, Eq. (11.85)}$$

$$F_{ax,Rd} = \min \begin{cases} \pi \cdot d \cdot l_a \cdot f_{vr,d} = \pi \cdot 24 \cdot 625 \cdot 1.98 \cdot 10^{-3} \\ \frac{k_{mod}}{\gamma_M} \cdot E_s \cdot A_s \cdot \varepsilon_{u,tim} = \frac{0.9}{1.3} \cdot 210000 \cdot 353 \cdot 0.0022 \cdot 10^{-3} \\ K_c \cdot N_{pl,d} = 0.706 \cdot 205.38 \end{cases}$$

$$F_{ax,Rd} = \min \begin{cases} 93.31 \text{ kN} \\ 112.91 \text{ kN} = 93.31 \text{ kN} \\ 145 \text{ kN} \end{cases}$$

Maximum load per threaded rod under pressure (compression):

$$F_{c,d} = F_{n,ax,d} = -4.66$$

$$\frac{|F_{c,d}|}{F_{ax,Rd}} = \frac{4.66}{93.31} = 0.05 \leq 1$$

EN 1990-1-1, Eq. (6.8), verification fulfilled ✓

Shear force on the threaded rod:

$$f_{h,k} = 0.1 \cdot 0.082 \cdot (1 - 0.01 \cdot d_{drill}) \cdot p_k$$

EN 1995-1-1:2025, 11.10.6 (2) (3)

$$f_{h,k} = 0.1 \cdot 0.082 \cdot (1 - 0.01 \cdot 26) \cdot 365 = 2.21 \text{ N/mm}^2$$

Characteristic value of the yield moment:

$$d_{sp} = 0.86 \cdot d$$

EN 1995-1-1:2025, Table 11.7

$$M_{y,k} = 0.3 \cdot f_{u,k} \cdot d_{sp}^{2.6}$$

EN 1995-1-1:2025, Table 11.7

$$d_{sp} = 0.86 \cdot 24 = 20.6 \text{ mm}$$

$$M_{y,k} = 0.3 \cdot 800 \cdot 20.6^{2.6} = 625,555.7 \text{ Nmm}$$

$$t_h = l_w$$

$$l_{can} = l_{nb} + e = 0$$

$$F_{D,k} = \min \begin{cases} d_{drill} \cdot f_{h,k} \left(\sqrt{(t_h + 2l_{can})^2 + t_h^2} - t_h - 2l_{can} \right) (a) \\ d_{drill} \cdot f_{h,k} \left(\sqrt{l_{can}^2 + \frac{2 \cdot M_{y,k}}{d \cdot f_{h,k}}} - l_{can} \right) (b) \end{cases} \quad \text{EN 1995-1-1:2025, Eq. (11.93)}$$

$$F_{D,k} = \min \begin{cases} 26 \cdot 2.21 \left(\sqrt{(625 + 0)^2 + 625^2} - 625 - 0 \right) = 14,875 \text{ N} \\ 26 \cdot 2.21 \left(\sqrt{0 + \frac{2 \cdot 625,555.7}{24 \cdot 2.21}} - 0 \right) = 8,825 \text{ N} \end{cases} = 8,825 \text{ N}$$

$$F_{D,d} = \frac{n_{ef}}{n} \cdot \frac{F_{D,k}}{\gamma_M} \cdot k_{mod} = \frac{(n_y \cdot n_z)^{0.9}}{n_y \cdot n_z} \cdot \frac{F_{D,k}}{\gamma_M} \cdot k_{mod} \quad \text{EN 1995-1-1:2004, Eq. (8.41)}$$

$$F_{D,d} = \frac{(1.2)^{0.9}}{1.2} \cdot \frac{8.825}{1.3} \cdot 0.9 = 5.7 \text{ kN}$$

$$\frac{|F_{v,d}|}{F_{D,d}} = \frac{3.1}{5.7} = 0.54 \leq 1$$

EN 1990-1-1, Eq. (6.8), verification fulfilled ✓

Combined forces:

Interaction exponent, p : 1

EN 1995-1-1:2025, Table 11.11

Tension and shear forces:

$$F_{ax,Rd} = \min \begin{cases} F_{t,Rd} = 173.78 \text{ kN} \\ F_{w,Rd} = 93.31 \text{ kN} \end{cases} = 93.31 \text{ kN}$$

$$\left(\frac{|F_{ax,Ed}|}{F_{ax,Rd}} \right)^p + \left(\frac{|F_{v,d}|}{F_{D,d}} \right)^p \leq 1.0 \quad \text{EN 1995-1-1:2025, Eq. (11.22)}$$

$$\left(\frac{|19.66|}{93.31} \right)^1 + \left(\frac{|3.1|}{5.7} \right)^1 = 0.75 \leq 1.0 \quad \text{verification fulfilled} \checkmark$$

Compression and shear forces:

$$\left(\frac{|F_{c,d}|}{F_{ax,Rd}} \right)^p + \left(\frac{|F_{v,d}|}{F_{D,d}} \right)^p \leq 1 \quad \text{EN 1995-1-1:2025, Eq. (11.22)}$$

$$\left(\frac{|-4.66|}{93.31} \right)^1 + \left(\frac{|3.1|}{5.7} \right)^1 = 0.59 \leq 1 \quad \text{verification fulfilled} \checkmark$$

Summary of verifications

Verifications in the timber member

Tension load-bearing capacity:

$$\frac{n_y \cdot F_{max,ax,d}}{F_{t,0,Rd}} \leq 1 = \frac{1 \cdot 19.66}{237.8} = 0.08 \leq 1.0$$

Verifications on the threaded rod

Tension loaded steel rod:

$$\frac{F_{max,ax,d}}{R_{ax,d}} = \frac{19.66}{173.78} = 0.11 \leq 1.0$$

Compression loaded steel rod:

$$\frac{|F_{c,d}|}{F_{ax,Rd}} = \frac{4.66}{93.31} = 0.05 \leq 1.0$$

Shear loaded steel rod:

$$\frac{|F_{v,d}|}{F_{D,d}} = \frac{3.1}{5.7} = 0.54 \leq 1.0$$

Combined force loaded steel rod:

$$0.75 \leq 1.0$$

Verifications on the adhesive

Adhesive joint withdrawal:

$$\frac{F_{max,ax,d}}{F_{w,Rd}} = \frac{93.31}{173.78} = 0.21 \leq 1.0$$

5.3 Design Example no. 3: Transverse compression reinforcement

Description of the application: 1x2 diameter M16 Hilti 8.8 AM steel grade threaded rods are installed in a glue-laminated timber member using Hilti HIT-RE 500 V4 to strengthen the timber member against transverse compression force (Fig. 5.8).

Geometry:

Timber member: $b \times h = 200 \times 700 \text{ mm}$
 Edge distance: $a_{2,c} = 50 \text{ mm}$; $a_{1,c} = 70 \text{ mm}$;
 Spacing: $a_2 = 100 \text{ mm}$
 Support width: $b_{c,90} = 180 \text{ mm}$
 Support length: $l_{c,90} = 100 \text{ mm}$
 Overhang: $l_e = 20 \text{ mm}$

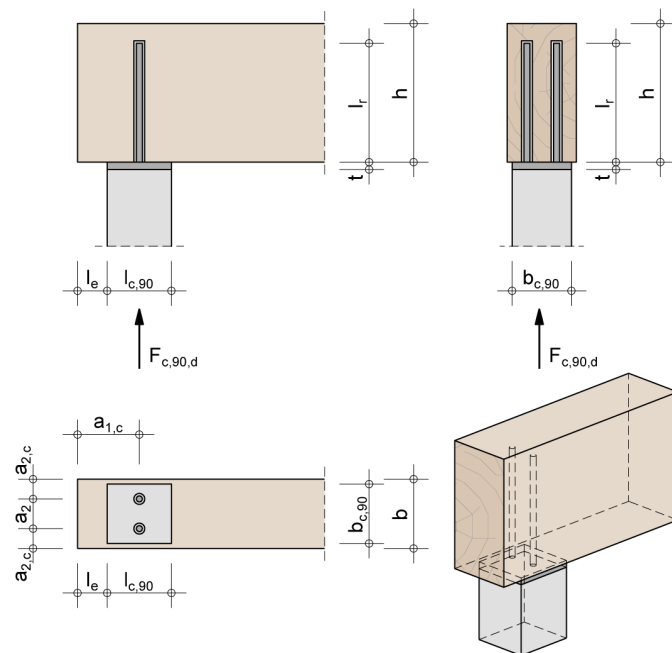


Fig. 5.8: Details of the connection

Loading:

Compression force: $F_{c,90,d} = 120 \text{ kN}$
 Load duration class: Medium, $k_{mod} = 0.8$
 Service class: Covered open structures, 2

Material property of the timber:

Engineered timber product: Glue-laminated timber
 Strength class: GL24c
 Characteristic tensile strength: $f_{t,0,k} = 17 \text{ N/mm}^2$
 Characteristic shear strength: $f_{v,k} = 3.5 \text{ N/mm}^2$

Characteristic compression strength: $f_{c,90,k} = 3.5 \text{ N/mm}^2$

Modification factor splitting and degree of compressive deformation: $k_{c,90} = 1.75$

Failure strain of the timber parallel to the grain: $\varepsilon_{u,tim} = 0.0022$

Connector:

Diameter: 16 mm

Layout: $n_x = 1$; $n_y = 2$

Embedment depth: $l_r = 500 \text{ mm}$

Threaded rod steel grade: 8.8

Ultimate strength of the threaded rod: $f_{uk} = 800 \text{ N/mm}^2$

Yielding strength of the threaded rod: $f_{yk} = 640 \text{ N/mm}^2$

Young module: $E_s = 210,000 \text{ N/mm}^2$

Cross section of the threaded rod: $A_s = 157 \text{ mm}^2$

Installation method of the connector and parameters:

Installation method: Direct filling

Drilling diameter: 18 mm

Not-bonded length: $l_{nb} = 0 \text{ mm}$

Drilling length: $l_{drill} = 625 \text{ mm}$

Annular gap: $t_b = 1 \text{ mm}$

Pressure distribution plate:

Plate thickness: $t = 10 \text{ mm}$

Yielding strength of the plate: $f_{y,k} = 235$

Verification of the minimum distances in the timber member:

$$a_{1,c} = 70 \text{ mm} \geq a_{1,c,min} = 2.5d = 40 \text{ mm} \quad \text{EOTA TR 070, Table 4.1}$$

$$a_2 = 100 \text{ mm} \geq a_{2,min} = 4d = 64 \text{ mm} \quad \text{EOTA TR 070, Table 4.1}$$

$$a_{2,c} = 50 \text{ mm} \geq a_{2,c,min} = 2.5d = 40 \text{ mm} \quad \text{EOTA TR 070, Table 4.1}$$

verification fulfilled

Verification of lateral compression load-bearing capacity (without reinforcement):

$$A_{ef,1} = b_{c,90} \cdot (l_{c,90} + 30 + \min\{30; l_e\}) \quad \text{EN 1995-1-1:2008/A1, 6.1.5(1)[12]}$$

$$A_{ef,1} = 180 \cdot (100 + 30 + \min\{30; 20\}) = 27000 \text{ mm}^2$$

$$f_{c,90,d} = k_{mod} \cdot \frac{f_{c,90,k}}{\gamma_m} = 0.8 \cdot \frac{2.5}{1.30} = 1.54 \text{ N/mm}^2 \quad \text{EN 1995-1-1:2004, Eq. (2.14)}$$

$$F_{c,90,Rd} = A_{ef,1} \cdot k_{c,90} \cdot f_{c,90,d} = 2700 \cdot 1.75 \cdot 1.54 \cdot 10^{-3} = 72.77 \text{ kN} \quad \text{EN 1995-1-1:2008/A1, Eq. (6.3-6.4)}$$

$$\frac{F_{c,90,d}}{F_{c,90,Rd}} = \frac{120.0}{72.77} = 1.65 \geq 1.0 \quad \text{verification not fulfilled, reinforcement required$$

Design – verifications for reinforcement:

Verification of lateral compression load-bearing capacity in area of the support (area-1):

Embedment length check:

$$l_{a,min} = \max(0.5d^2; 10d; 100 \text{ mm}) = \max(128; 160; 100) = 160 \text{ mm} \leq l_r = 500 \text{ mm} \quad \text{EOTA TR 070, (4.4)}$$

$$l_{a,max} = \min(40d; 1000 \text{ mm}) = \min(640; 1000) = 640 \text{ mm} \geq l_r = 500 \text{ mm} \quad \text{ETA-20/0384}$$

Adhesive joint strength:

$$f_{vr,k} = 5.55 - 0.005 \cdot l_r = 5.55 - 0.005 \cdot 500 = 3.05 \text{ N/mm}^2 \quad \text{ETA-20/0384}$$

$$f_{vr,d} = k_{mod} \cdot \frac{f_{vr,k}}{\gamma_m} = 0.8 \cdot \frac{3.05}{1.30} = 1.88 \text{ N/mm}^2 \quad \text{EOTA TR 070, Eq. (4.3)}$$

Resistance to buckling:

$$E_s \cdot I_s = \frac{210000 \cdot A_s^2}{\pi \cdot 4} = \frac{210000 \cdot 157^2}{\pi \cdot 4} = 411,916,070 \text{ Nmm}^2 \quad \text{Z-9.1-791, Eq. (10)}$$

$$c_h = (0.19 + 0.012 \cdot d) \cdot \rho_k \cdot \left(\frac{90 + \alpha}{180} \right) \quad \text{ETA-22/0772}$$

$$c_h = (0.19 + 0.012 \cdot 16) \cdot 365 \cdot \left(\frac{90 + 90}{180} \right) = 139.43 \text{ N/mm}^2$$

$$N_{ki,k} = \sqrt{c_h \cdot E_s \cdot I_s} = \sqrt{139.43 \cdot 411,916,070} \cdot 10^{-3} = 239.65 \text{ kN} \quad \text{Z-9.1-791, Eq. (8)}$$

$$N_{pl,k} = A_s \cdot f_{y,k} = 1.57 \cdot 640 \cdot 10^{-1} = 100.48 \text{ kN} \quad \text{Z-9.1-791, Eq. (6)}$$

$$N_{pl,d} = \frac{N_{pl,k}}{\gamma_m} = \frac{100.48}{1.1} = 91.35 \text{ kN} \quad \text{Z-9.1-791, Eq. (7)}$$

$$\lambda_k = \sqrt{\frac{N_{pl,k}}{N_{ki,k}}} = \sqrt{\frac{100.48}{239.7}} = 0.65 \quad \text{Z-9.1-791, Eq. (5)}$$

$$k = 0.5 \cdot [1 + 0.49 \cdot (\lambda_k - 0.2) + \lambda_k^2] = 0.5 \cdot [1 + 0.49 \cdot (0.65 - 0.2) + 0.65^2] = 0.82 \quad \text{Z-9.1-791, Eq. (4)}$$

$$k_c = \frac{1}{k + \sqrt{k^2 - \lambda_k^2}} = \frac{1}{0.82 + \sqrt{0.82^2 - 0.65^2}} = 0.755 \quad \text{Z-9.1-791, Eq. (3)}$$

$$F_{ax,Rd} = \min \begin{cases} \text{Adhesive joint strength} \\ \text{Expansion capacity of the timber} \\ \text{Buckling resistance} \end{cases} \quad \text{EN 1995-1-1:2025, Eq. (11.85)}$$

$$F_{ax,Rd} = \min \begin{cases} \pi \cdot d \cdot l_a \cdot f_{vr,d} = \pi \cdot 20 \cdot 500 \cdot 1.88 \cdot 10^{-3} \\ \frac{k_{mod}}{\gamma_M} \cdot E_s \cdot A_s \cdot \epsilon_{u,tim} = \frac{0.8}{1.3} \cdot 210000 \cdot 157 \cdot 0.0022 \cdot 10^{-3} \\ K_c \cdot N_{pl,d} = 0.755 \cdot 91.35 \end{cases}$$

$$F_{ax,Rd} = \min \begin{cases} 47.25 \text{ kN} \\ 44.64 \text{ kN} \\ 68.97 \text{ kN} \end{cases}$$

$$F_{1,90,Rd} = F_{c,90,Rd} + n_x \cdot n_y \cdot F_{ax,Rd} = 72.77 + 1 \cdot 2 \cdot 44.64 = 162.05 \text{ kN}$$

$$\frac{F_{c,90,d}}{F_{1,90,Rd}} = \frac{120}{162.05} = 0.74 \leq 1.00$$

verification fulfilled ✓

Verification of lateral compression load-bearing capacity in area of the threaded rod ends (area-2):
(Fig. 5.9)

Representation according to EN 1995-1-1:2025, Figure 8.5:

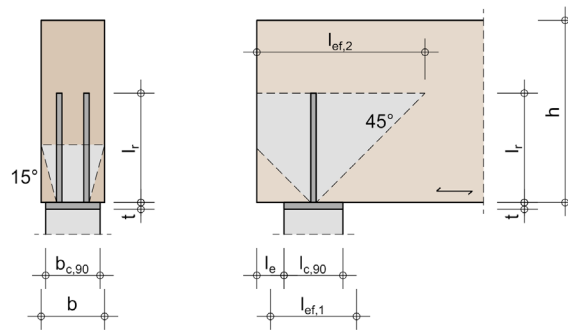


Fig. 5.9: Details of the connection according to EN 1995-1-1:2025

$$b_{ef,2} = \min \left\{ \begin{array}{l} b = 200 \text{ mm} \\ (n_y - 1) \cdot a_2 + 2 \cdot l_r \cdot \tan 15 = (2 - 1) \cdot 100 + 2 \cdot 500 \cdot \tan 15 = 368 \text{ mm} \end{array} \right\}$$

$$b_{ef,2} = 200 \text{ mm}$$

$$l_{ef,2} = l_r + (n_x - 1) \cdot a_1 + \min(l_r ; a_{1,c}) = 500 + 0 \cdot 64 + \min(500 ; 70) = 570 \text{ mm}$$

$$A_{ef,2} = b_{ef,2} \cdot l_{ef,2} = 200 \cdot 570 = 114\,000 \text{ mm}^2$$

$$F_{2,90,Rd} = A_{ef,2} \cdot f_{c,90,d} = 114\,000 \cdot 1.54 \cdot 10^{-3} = 175.56 \text{ kN}$$

$$\frac{F_{c,90,d}}{F_{2,90,Rd}} = \frac{120}{175.56} = 0.68 \leq 1.00$$

verification fulfilled ✓

Summary of verifications

Lateral compression load-bearing capacity: $\frac{F_{c,90,d}}{F_{c,90,Rd}} = \frac{120.0}{72.77} = 1.65 \geq 1.0$

Lateral compression load-bearing capacity in the support (area-1): $\frac{F_{c,90,d}}{F_{1,90,Rd}} = \frac{120}{162.05} = 0.74 \leq 1.0$

Lateral compression load-bearing capacity in the threaded rod ends (area-2): $\frac{F_{c,90,d}}{F_{2,90,Rd}} = \frac{120}{175.56} = 0.68 \leq 1.0$

6. Summary

Glued-in rod (GiR) systems provide high load-bearing capacity, design flexibility, and efficient solutions for both new construction and retrofit applications by helping to enable reliable force transfer and effective reinforcement of structural elements. Building on these advantages, this technical guide presents Hilti glued-in rod solutions and explains the applications in connection and reinforcement systems for various base material combinations. The guide also highlights the advanced GiR software module, which helps to facilitate easier, safer, and more efficient design. In addition, relevant design methods and verification approaches are introduced with different worked-out design examples to support designers and structural engineers with clear and practical guidance.

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