HIT-SHEAR

Manual
HIT-Shear Reinforcement System

Version 1.02 EN
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INHALT

1. EFFICIENT SHEAR STRENGTHENING OF REINFORCED CONCRETE MEMBERS WITH HIT-SHEAR

Many existing structures and bridge components do not longer meet the shear capacity requirements according to Eurocode 2. To ensure their safety and durability, a strengthening solution is necessary. Our shear reinforcement system offers a certified and sustainable solution for this challenge.

With our HIT-Shear shear reinforcement system, you can achieve increased load-bearing capacities in compliance with standards and approvals for building construction, civil and structural engineering (Figure 1).

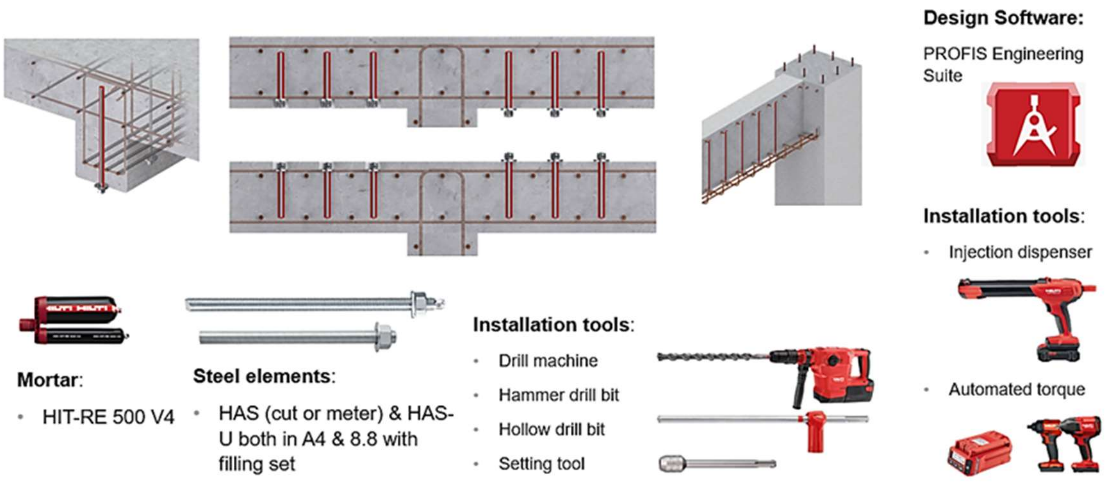


Fig 1: Main Hilti HIT-Shear shear reinforcement system

The system is based on high-strength threaded rods that are vertically bonded into the existing structural element using injection mortar (HIT-Shear elements) to strengthen the reinforced concrete member. The design is carried out in accordance with EN 1992-1-1 and the relevant German national approval (AbG).

The threaded rods act as reinforcement elements and are securely anchored in the concrete using Hilti’s proven high-performance adhesive mortar HIT-RE 500 V4. The load transfer between the threaded rod and the mortar is achieved through micro-keying, while the forces are further transmitted from the mortar into the concrete by adhesive bond (Figure 2). This approach is based on well-established methods from fastening technology, which have been successfully used in practice for decades.

The HIT-Shear shear reinforcement system functions similarly to stirrup reinforcement. Crucial for its effectiveness is the optimal positioning of the reinforcement: it should extend as close as possible to the height of the longitudinal reinforcement in the compression zone while also being anchored as close as possible to the tension side.

This arrangement replicates the stirrup hook required by Eurocode 2 as accurately as possible. As a result, the shear reinforcement spans the entire cross-section height, ensuring maximum effectiveness. Careful planning and the use of semi-automatic drilling rigs support this approach and helps to reach optimal results.

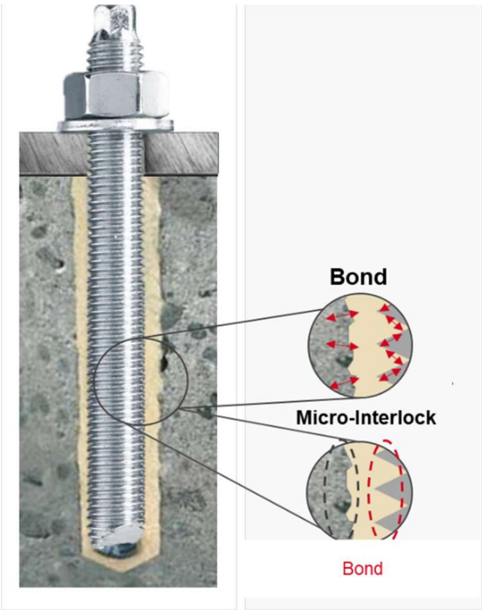


Fig 2: Introduction of loads into the concrete through material bonding

The Hilti shear reinforcement system is highly versatile and can be used in reinforced concrete and prestressed concrete components made from normal concrete with strength classes ranging from C20/25 to C50/60.

It is suitable for static, quasi-static, and fatigue loads. The structural element to be strengthened must have a minimum thickness of h_{min} = 200 mm while the maximum component thickness for shear reinforcement is h_{max} = 2200 mm.

To meet various project requirements, the threaded rods are available in sizes from M12 to M24, with options in either zinc-plated or stainless steel versions, ensuring high flexibility for different applications.

Our system solution covers the entire process from planning to installation:

- The PROFIS Engineering Suite helps you design precisely and efficiently.
- Detection of existing reinforcement using advanced concrete scanners helps you avoiding cutting of existing reinforcement.
- Drilling and cleaning of boreholes in a single step with semi-automatic drilling tools boosts your productivity on site.
- Fast and precise filling of boreholes with injection devices helps you minimizing mortar wastage.

The single step drilling, no drill bit changes, and specific torque requirements, significantly reduce installation time.

We are happy to provide tailored advice on how to best plan shear reinforcement for reinforced concrete components and incorporate it into your specifications. Get in touch with us – our expertise and experience are at your service!

1.1 The 5 Key Benefits of the HIT-Shear System Solution

1. Certified and Approved Solution

- Reliable and standards-compliant work with tested systems

2. Comprehensive System Solution for Shear Reinforcement
The workflow includes:

- Planning and structural design
- Detection of existing reinforcement using concrete scanners

- Precise calculation of mortar volume
- Drilling and cleaning in a single step with semi-automatic drilling tools
- Fast and accurate borehole filling with injection devices

3. Simple and Safe Design with PROFIS Engineering Software

- Free to use
- Compliant with EN 1992-1-1 and German national approval
- Allows division of the component into different shear zones
- Helps to significantly reduce the time for assessment of the reinforced concrete member and design of the strengthening solution

4. Avoidance of Unintended Bending Moments

- Thanks to the Hilti filling set, even when threaded rods are inclined to the surface (e.g., in bridge construction)

5. Variable Strut Angle

- Flexibility through angles ranging from 18.4° to 45°

2. OPTIMIZED PROCESS WITH THE HILTI SYSTEM SOLUTION

When planning strengthening measures, it is crucial to understand the close link between planning and execution, as execution is the realization of a design that must be practically feasible.

„System solutions for strengthening measures always outperform individual product solutions.

That is why Hilti has developed coordinated systems for all post-installed reinforcement applications, supporting you throughout every step of the process. This allows you to carry out post-installed reinforcement work faster, safer, and more cost-effectively. Our system solutions cover nearly all installation steps, creating a truly integrated approach.

1. Planning and Structural Design

The **PROFIS Engineering Suite** software enables you to flexibly plan, design, and document post-installed strengthening solutions efficiently, while adhering to current standards and regulations

2. Substrate Detection

Gain valuable insights into floors, walls, and ceilings. Hilti detection systems offer tailored solutions for your specific needs – from deep reinforcement detection to accurate utility location for non-destructive drilling.

Our systems at a glance:

- **Ferroscan System PS 300:**
  Perfect for precise detection of reinforcement bars, estimation of rebar diameters, and concrete cover measurement – reliable and accurate.

- **Concrete Detection System PS 1000 X-Scan:**
  Ideal for efficiently scanning large areas, detecting metal objects as well as non-metallic items such as pipes across multiple layers– fast and easy.

Find the right system for your application and benefit from cutting-edge technology for maximum efficiency and precision.

3. Fewer Work Steps Thanks to Coordinated Installation Systems

With **ETA-approved hollow drill bits** integrated into the system, borehole cleaning is automatically performed during drilling. This reduces labor time by up to **50%**. Additionally, installation errors due to inadequate borehole cleaning are minimized, and workers benefit from effective dust protection.

Furthermore, **battery-powered rotary hammers and chisels with Active Torque Control (ATC)** increase workplace safety by minimizing the risk of injuries. For particularly precise drilling under challenging conditions, **semi-automatic drilling rigs** are available (see Figure 3).

4. How You Save Time and Costs

Our innovative solution helps you optimize borehole filling – efficiently and safely:

- **Exact Mortar Calculation:**
  The **Hilti mortar calculator app** allows you to calculate the required mortar quantity in advance with precision. This enables you to plan your repair project with the highest accuracy and avoid material waste.

- Precise Application:
  Battery-powered injection devices with dosing function allow you to effortlessly and precisely fill boreholes with the exact calculated amount – without wasting a drop.

The result?
Up to 20% less mortar consumption, leading to significant cost savings. Take advantage of smart technology that makes your work faster, safer, and more cost-efficient!

5. We Are Here for You

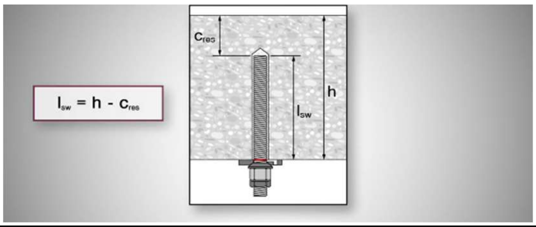
You can always rely on Hilti's engineers, technicians, and consultants. If you wish, we will work closely with you to ensure the success of your repair project. We support you with detailed planning, calculation, and cost estimation – and we are available on-site to help you overcome any challenges you may face.

Fig. 3: Hilti semi-automatic drilling systems

2.1 Installation process (schematic)

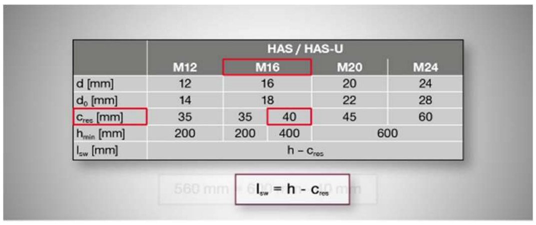
All products must be used and applied in accordance with Hilti's specifications (see technical instructions, user manuals, setting and installation guidelines, etc.)

Step 1: Localization and marking of existing reinforcement bars, stirrups, and other embedded elements on the concrete surface according to specifications



Step 2: Marking the drilling position on the concrete surface according to the specification or detailed planning.

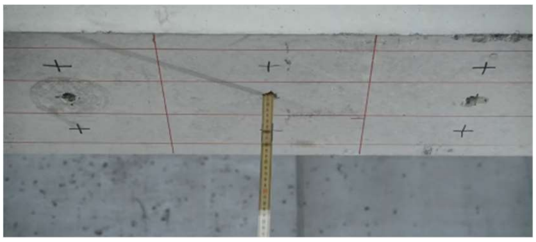
Step 3: The required drilling depth l_{sw} must be determined based on the component height h and the remaining concrete cover c_{res} according to the specification, detailed planning, or installation instructions.



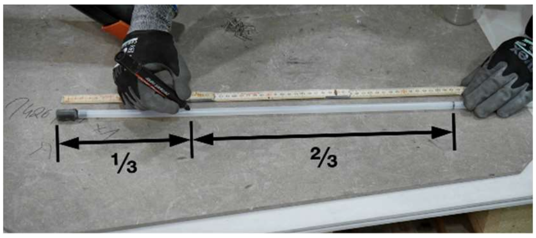
	HAS / HAS-U				
	M12	M16		M20	M24
d [mm]	12	16		20	24
d_0 [mm]	14	18		22	28
c_{res} [mm]	35	35	40	45	60
h_{min} [mm]	200	200	400	600	
l_{sw} [mm]	h – c_{res}				

Example of the required drill hole depth according to the installation instructions and national approval (abG).

Step 4: The drill hole must be created at the designated position according to the specification and detailed planning using the specified drilling method (hollow drill bit, hammer drill bit, or diamond drill bit) until the required depth l_{sw} is reached.



Step 5: Verification of the actual drill hole depth against the required drill hole depth and documentation if required.



Step 6: Marking the required drill hole depth on the extension hose and dividing the total length in a 1/3 to 2/3 ratio, starting from the end of the retention nozzle.

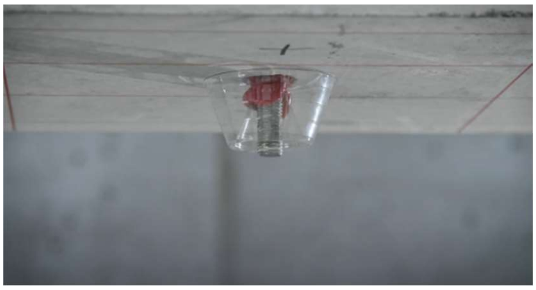
Step 7: Preparation of the threaded rod with Hilti drip plate HIT-OHC2.

Step 8: Preparation of the specified injection system, including all required accessories.

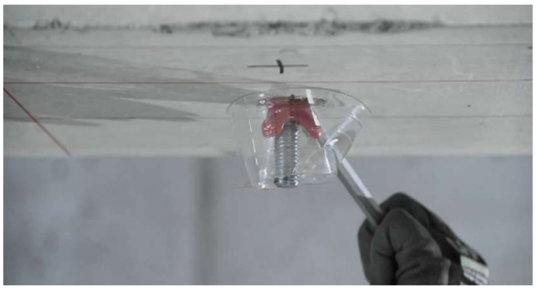
Step 9: Discarding the first strokes as specified in the installation instructions to ensure proper mixing of resin and hardener.

Step 10: Injection of the drill hole from the bottom up within the working time using appropriate accessories to ensure bubble-free filling and sufficient mortar quantity.

Step 11: Inserting the threaded rod to the bottom of the drill hole, followed by a visual inspection to confirm that a sufficient amount of mortar is visible at the drill hole opening.



Step 12: Aligning and securing the threaded rod with the Hilti wedge HIT-OHW.



Step 13: Removing the drip plate and excess mortar at the drill hole opening after the curing time specified in the installation instructions.

Step 14: Installation of the Hilti filling set manually or using the SI-AT-22 Adaptive Torque Module, ensuring all components are considered and the maximum torque is observed.

Step 15: Tighten the lock nut hand-tight.

Step 16: Filling the Hilti sealing disc with suitable Hilti injection mortar using 1–3 strokes, as specified in the installation instructions.

Note: Depending on the applicable building regulations, legal requirements, or other provisions of the respective country, an installation report may need to be created and retained for each shear element if required by law or contractual agreements.

3. REVIEW: STRUCTURAL MODEL OF A REINFORCED CONCRETE BEAM

A reinforced concrete beam with longitudinal and shear reinforcement is characterized by four main structural elements (see Figure 4):

1. A concrete compression chord mainly made of concrete due to bending,
2. A tension chord made of longitudinal reinforcement due to bending,
3. Concrete compression struts,
4. Vertical tension ties made of shear reinforcement, connecting the compression and tension chords.

These elements form a structural model that functions similarly to a truss. This model was developed by Mörsch and Ritter in the early 20th century and helps engineers visualize the load paths within a beam.

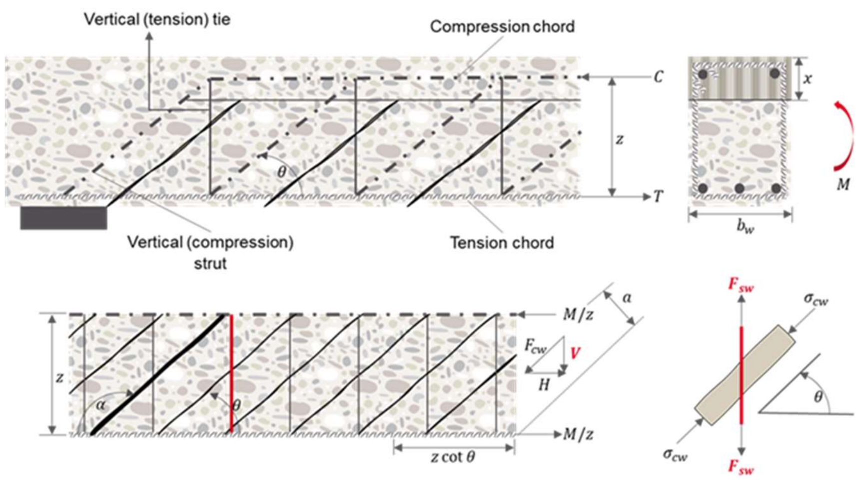


Fig. 4: A reinforced concrete beam with shear reinforcement, represented by the Mörsch-Ritter truss model, including the compression and tension chord, the inclined compression strut, and the vertical tension tie [5] & [6].

3.1 Requirements for Shear Reinforcement

For the truss model to function reliably in resisting shear forces, the shear reinforcement must enclose (or hook around) the compression chord to act as a tension tie, enabling force transfer at the node.

In practice, this requirement can be fulfilled through:

- Bond between concrete and reinforcement,
- Concrete tensile strength, or
- A direct connection, which is the most common approach.

The direct connection is typically achieved using shear reinforcement with bent ends, either with or without additional longitudinal reinforcement in the compression zone.

The **HIT-Shear system** meets all these requirements through indirect anchorage within the compression zone, providing a simple and efficient solution to safely transfer shear forces and reliably increase the load-bearing capacity of beams.

4. DESIGN OF REINFORCED CONCRETE COMPONENTS FOR SHEAR CAPACITY

4.1 General Principals

According to **Eurocode 2 (EN 1992-1-1)**, a distinction is made between structural components **with and without shear reinforcement**. Shear reinforcement can be omitted if the applied shear force is lower than the shear capacity of the uncracked concrete — meaning that the concrete alone is capable of safely resisting the existing forces.

According to Eurocode 2, this is particularly the case for:

- **Lightly loaded components**, such as floor slabs or large-area foundations, which, due to their wide cross-section and low loads, do not require additional shear reinforcement.
- **Components without concentrated loads**, where the shear force is evenly distributed, and no critical stresses arise that could cause cracks.

However, shear reinforcement becomes necessary when:

- **Concentrated loads occur**, such as in beams with large spans, column support areas, or bridge girders, where increased shear stresses could overload the concrete without reinforcement.
- **The shear capacity of uncracked concrete is exceeded**, leading to the formation of diagonal cracks, which may compromise the component's load-bearing capacity.
- **Adequate ductility is required** to safely transfer forces after cracks have formed.

4.2 Verification Without Shear Reinforcement According to EN 1992-1-1 & SIA 262:2013

The design of the shear capacity of concrete components without shear reinforcement is specified differently in various standards, such as **EN 1992-1-1** and the **SIA standard** (Swiss Society of Engineers and Architects). These differences arise from national practices and the underlying local testing methods that have been developed over decades.

Although the equations and approaches differ, they often lead to **comparable results in practice**, as the fundamental principles of shear design are largely similar.

- Shear Capacity Without Shear Reinforcement (EN 1992-1-1):

$$V_{Rd,c} = \left[C_{Rd,c} k (100 \rho_l f_{ck})^{\frac{1}{3}}\right] b_w \cdot d \qquad (1)$$

In SIA 262:2013, there are minor differences in the design of the load-bearing capacity of concrete elements without shear reinforcement.

Shear Capacity Without Shear Reinforcement (SIA 262:2013): $V_{Rd} = k_d \tau_{cd} d_v b_w$ (2)

4.3 Verification with Shear Reinforcement according to EN 1992-1-1 & SIA 262:2013

A central feature of modern design codes is the assumption that the intended shear reinforcement (see Figure 5) must carry all remaining shear forces when the concrete alone is no longer capable of resisting them. Similar to the diagonal compression struts in an open truss system, the inclination angle θ of the compression struts plays a crucial role. This angle influences:

- The maximum resistance of the concrete compression strut before strut failure ($\boldsymbol{V_{Rd,max}}$), and
- The resistance of the shear reinforcement before yielding ($\boldsymbol{V_{Rd,s}}$).
- The smaller of these two values determines the total shear capacity $\boldsymbol{V_{Rd}}$ of the structural element.

When the design requires shear reinforcement, three criteria are decisive in determining the necessary amount:

- Minimum cross-sectional area $\boldsymbol{A_{sw,min}}$: Sufficient shear reinforcement must be provided to prevent yielding as soon as the first shear cracks appear.
- Required cross-sectional area $\boldsymbol{A_{sw}}$: The amount of shear reinforcement must be sufficient to safely carry the applied design load.
- Reinforcement ratio $\boldsymbol{\rho_{w}}$: The ratio between the shear reinforcement and the concrete cross-section must be chosen to ensure yielding of the reinforcement while preventing brittle failure of the compression strut.

Codes such as EN 1992-1-1:2004 and SIA 262:2013 use the truss model or the stress field model to determine the required shear reinforcement. They rely on a consistent design formula, differing only slightly in the limit values for the compression strut angle θ.

This ensures a uniform approach that enables the safe design of structural elements with shear reinforcement.

- Yield force per stirrup: $F_{wi} = A_{sw} \cdot f_{ywd}$ (3)
- Number of stirrups inside Δx: $n = \frac{z \cdot cot\,(\alpha)}{s}$ (4)
- All stirrup forces inside Δx: $\boldsymbol{V_{Rd,s} = f_{ywd} \cdot A_{sw} \cdot \frac{z \cdot cot\theta}{s}}$ (5)
- If the stirrups are inclined ($\alpha \neq 90°$): $V_{Rd,s} = f_{ywd} \cdot \frac{A_{sw} \cdot z}{s} \cdot (cot\theta + cot\alpha) \cdot sin\alpha$ (6)
    - According to EN 1992-1-1:2004, the stirrup inclination is $45° \leq \alpha \leq 90°$, the minimum shear reinforcement ratio is: $\rho_{w,min} = 0{,}08 \cdot \frac{\sqrt{f_{ck}}}{f_{yk}}$ (7)
    - According to **SIA 262:2013** the stirrup inclination is $45° \leq \beta \leq 90°$, he minimum shear reinforcement ratio is $\rho_{w,min} = 0{,}001 \cdot \sqrt{\frac{f_{ck}}{30}} \cdot \frac{500}{f_{sk}}$ (8)

Design value of the shear resistance provided by the concrete compression strut:

$$\boldsymbol{V_{Rd,max} = \frac{b_w \cdot z \cdot \alpha_{cw} \cdot v_1 \cdot f_{cd}}{\cot\theta + \tan\theta}} \tag{9}$$

The maximum effective amount of shear reinforcement is calculated from the same model using the following equation (assuming that cotθ = 1):

$$\frac{A_{sw,max} \cdot f_{ywd}}{b_w \cdot s} \leq \frac{1}{2} \alpha_{cw} \cdot v_1 \cdot f_{cd} \tag{10}$$

Assumption of a variable compression strut angle: $\left(\frac{A_{sw}}{s}\right)_{max} \leq \frac{\alpha_{cw} \cdot v_1 \cdot f_{cd}}{f_{ywd}} \cdot b_w \cdot \sin^2\theta$ (11)

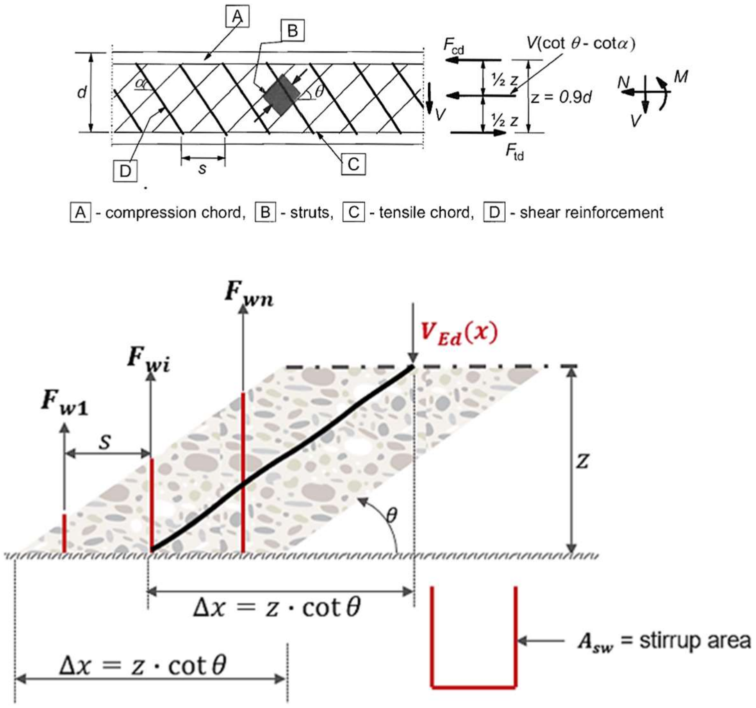


Fig. 5: Design model for shear capacity with shear reinforcement: (top) Truss model from EN 1992-1-1:2004 [8]; (bottom) Sketch with vertical stirrups.

The inclination angle $\boldsymbol{\theta}$ increases proportionally to the magnitude of the shear force acting on a concrete element. The design approach allows the structural engineer to select a larger compression strut inclination angle within a specified range.

A higher angle increases the resistance of the compression strut, enabling it to carry higher applied shear forces $\boldsymbol{V_{Ed}}$. However, this reduces the contribution of the shear reinforcement, which in turn requires a greater amount of reinforcement to meet the design requirements, as illustrated in Figure 6.

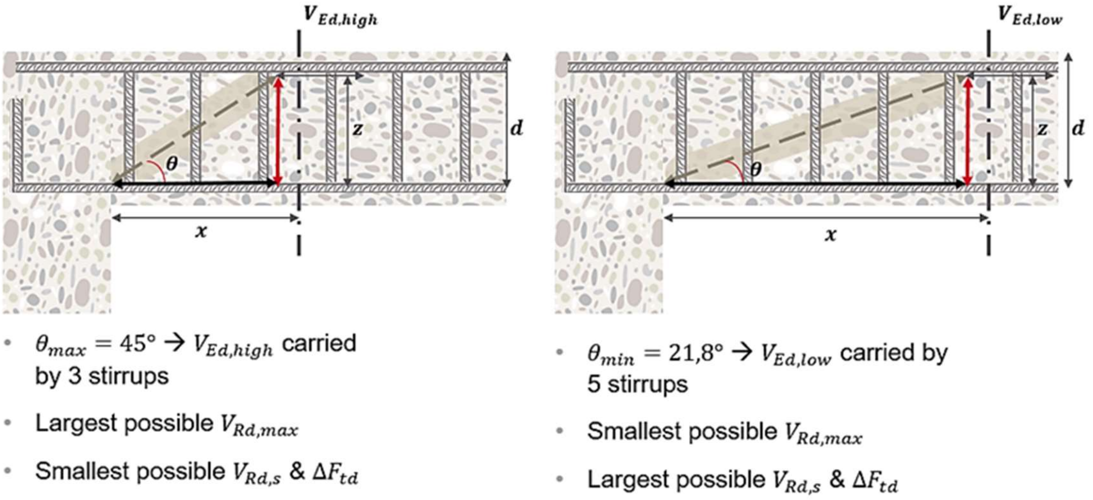


Fig. 6: Schematic representation of the influence of the inclination of the compression strut on the resistance of the compression strut and the shear reinforcement: (left) maximum and (right) minimum permissible inclination.

4.4 Optimization of Shear Design by Adjusting the Compression Strut Angle θ

If the inclination angle of the compression struts θ is reduced for an applied shear force V_{Ed}, the following effects occur:

1. Increased forces in the inclined compression struts:
    - A flatter inclination results in a higher force in the compression struts, which can lead to concrete failure at a lower shear force V_{Ed}.
    - The shear force at which the concrete struts fail ($\boldsymbol{V_{Rd,max}}$) defines the maximum shear capacity of a cross-section.
    - Once this limit is reached, increasing resistance by adding more shear reinforcement ($\boldsymbol{V_{Rd,s}}$) is no longer effective, as the failure of the compression struts becomes the governing failure mode.
2. Wider distribution of shear reinforcement:
    - A flatter compression strut angle allows for the use of more stirrups to resist the shear force V_{Ed}.
    - As a result, the required amount of shear reinforcement decreases because multiple stirrups can contribute simultaneously to the load-bearing capacity.
3. Increased tensile forces in the longitudinal reinforcement:
    - A flatter compression strut inclination leads to higher tensile forces in the longitudinal reinforcement $\Delta\boldsymbol{F_{td}}$.
    - These additional tensile forces must be anchored appropriately by a sufficient anchorage length in the support areas.

Optimizing the compression strut angle θ allows for better utilization of the system's load-bearing capacity but also affects the failure behavior. A careful balance between the effects mentioned above is crucial to ensure a safe and economical design.

5. QUESTIONS AND CONSIDERATIONS FOR SELECTING SUITABLE POST-INSTALLED REINFORCEMENT MEASURES

Selecting the optimal post-installed reinforcement method for a structure requires a careful consideration of various factors. These considerations help ensure a well-informed decision that is both technically sound and economically efficient.

1. Purpose and Objective of the Post-Installed Reinforcement

- Why is reinforcement necessary?

Example: Is the reinforcement required to add an additional floor, support loads from new machinery, or repair damage caused by corrosion?

- Which structural element needs post-installed reinforcement?

Example: Is it a column, beam, slab, or foundation? Different elements require specific measures.

2. Required Increase in Load Capacity

- How much additional load capacity is needed?

Example: Should the capacity be increased by 20% to accommodate higher traffic loads, or is a doubling of the capacity required due to a change in building usage? Is only shear or also bending strengthening required? Different measures allow different degrees of strengthening.

3. Unloading the Structural Element before Reinforcement

- Does the element need to be temporarily unloaded before reinforcement?

Example: For heavily loaded beams, it may be necessary to relieve them with temporary supports before reinforcement to reduce stress during the intervention.

4. Project Size

- Are special materials or methods cost-efficient given the project size?

Example: For small projects like reinforcing a single beam, simple methods may be more economical.

- Smaller projects may benefit less from complex or material-intensive solutions.

Example: Complex prestressing systems are typically worthwhile only for large structures such as bridges or industrial halls.

5. Environmental Conditions

- What external influences (e.g., temperature, fire risk, corrosion) must be considered?

Example: In a tunnel, reinforcement must meet different fire protection requirements compared to a building.

- Is the existing concrete sufficiently strong to support the reinforcement securely?

Example: For older structures, it may be necessary to test the concrete's compressive strength to ensure suitability for the selected method.

6. Dimensional and Spatial Constraints

- Are there any restrictions regarding dimensions or spacing?

Example: In tight underground parking garages, space limitations can complicate certain measures (e.g., jacketing), while others may be more suitable (e.g., post-installed reinforcement as HIT-Shear).

7. Accessibility and Operational Requirements

- How accessible is the structural element for the application of the reinforcement and later maintenance?

Example: In difficult-to-access areas such as under bridges or in shafts, lightweight materials and minimally invasive methods are advantageous (Note: the use of HIT-Shear does not significantly increase the weight of the structure).

- Are there operational constraints, such as limited construction time?

Example: Reinforcing a slab in a hospital may require work to be carried out at night or on weekends to avoid disrupting operations.

- Does the element need to remain in service during reinforcement?

Example: Reinforcing a bridge may require maintaining partial traffic flow, which can influence the choice of method.

8. Aesthetic Requirements

- Should the reinforcement be visually discreet or architecturally appealing?

Example: In heritage buildings, discreet reinforcement is often preferred.

9. Availability and Costs

- Are the required materials, equipment, and qualified specialists available locally?

Example: Reinforcement with ultra-high-performance concrete (UHPC) or special CFRP laminates requires verifying local availability.

- What are the initial investments and life cycle costs of the reinforcement?

Example: Certain systems may have higher initial costs but can be more cost-effective in the long run due to increased durability and reduced maintenance.

6. PERFORMANCE CERTIFICATES FOR HIT-SHEAR

While cast-in shear reinforcement systems are widely used in the construction industry, there is currently no European Assessment Document (EAD) or harmonized standard (hEN) for post-installed shear strengthening systems for reinforced concrete elements. As a result, such systems require a performance assessment to evaluate their suitability for design and application in shear strengthening.

In such cases, Annex D of EN 1990:2002 [10] provides the possibility to develop a design equation based on a combination of tests and design models that meet the reliability requirements of EN 1990.

According to European Technical Assessment (ETA) - 20/0541 [11], the combination of Hilti HIT-RE 500 V4 epoxy mortar, HAS(-U) threaded rods made of carbon steel or stainless steel, and the Hilti filling set has already been assessed and approved as an bonded anchor system in concrete.

6.1 Test Program for Evaluating the HIT-Shear System

To assess the behavior of this innovative shear reinforcement solution, a comprehensive testing program was conducted to investigate the influence of the following key parameters on the shear capacity:

- Diameter, spacing, and embedment length of the threaded rods,
- Thickness of the concrete element,
- Concrete strength.

In addition, experimental tests were carried out under realistic site conditions to evaluate the robustness of the system, even under unfavorable installation conditions, such as:

- Eccentricities of the HIT-Shear elements relative to the component axis during installation,
- Unintentional inclinations of the HIT-Shear elements during installation,
- Presence of existing shear cracks under service load.

Based on this comprehensive experimental investigation, a shear capacity model was developed that meets the reliability requirements of Annex D of EN 1990. This model resulted in a design equation that complies with EN 1992-1-1 and is described in detail in the following section.

6.2 HIT-SHEAR Approved by DIBt

The entire test series, conducted at Ruhr University Bochum (RUB), was evaluated by DIBt and declared suitable for practical application.

The system has been granted a general technical approval (aBG Z-15.5-383), thereby meeting the national requirements for construction works in accordance with the Model Administrative Provisions – Technical Building Regulations (MVV TB).

The MVV TB serves as a template for the technical building regulations implemented at the federal state level in Germany.

7. DESIGN AND DETAILING WITH HILTI HIT-SHEAR

The new Hilti solution for shear reinforcement comprises the HIT-RE 500 V4 injection mortar, HAS or HAS-U threaded rods, in combination with the Hilti filling set, nuts, and washers. The installation process of this solution is similar to that of a bonded anchor:

- Drilling to a specified embedment depth, perpendicular to the concrete surface,
- Cleaning the drill holes to remove dust and debris,
- Injecting the mortar, followed by inserting the threaded rods,
- Once the mortar has hardened, the nuts are tightened hand-tight.

This solution is approved by the general technical approval (aBG) Z-15.5-383 issued by DIBt and applies the assessment-assisted design approach according to Annex D of EN 1990.

The applied resistance model is fully compatible with the design provisions in DIN EN 1992-1-1/NA [12] and DIN EN 1992-2/NA [13]. The required verifications comply with Equations (6.8) and (6.9) of DIN EN 1992-1-1/NA, which define the resistance of cast-in stirrup reinforcement as well as the maximum resistance of the concrete struts. Section 4 of this document explains the background of these equations.

The resistance model is also based on the variable strut inclination method, which allows for adjusting the strut angle to balance the forces between the concrete struts and the reinforcement elements. This can lead to more economical designs, as fewer threaded rods may be required.

The design verification requires compliance with Eq. 12:

$$V_{Ed} \leq V_{Rd} = min\ (V_{Rd,max}\ , V_{Rd,s}) \tag{12}$$

7.1 Verification of the Concrete Strut

When the subsequently installed HIT-Shear elements are embedded perpendicular to the longitudinal axis of the concrete member, the installation angle α is 90°.

The resistance of the concrete strut is determined according to Equation (6.9) of DIN EN 1992-1-1 in conjunction with DIN EN 1992-1-1/NA, NCI to 6.2.3(1), as follows:

$$V_{Rd,max} = \frac{\boldsymbol{b_{w,eff}} \cdot \alpha_{cw} \cdot z \cdot v_1 \cdot f_{cd}}{\cot\theta + \tan\theta} \tag{13}$$

Here, the effective width of the reinforced cross-section, $\boldsymbol{b_{w,eff}}$, replaces the total cross-sectional width, $\boldsymbol{b_w}$,while considering an eccentricity parameter, $\boldsymbol{e_{inst}}$. This parameter increases to a maximum of either 50 mm or $\boldsymbol{b_w/6}$, relative to the centroid of the beam, depending on the positioning of the HIT-Shear elements during installation (see Figure 7).

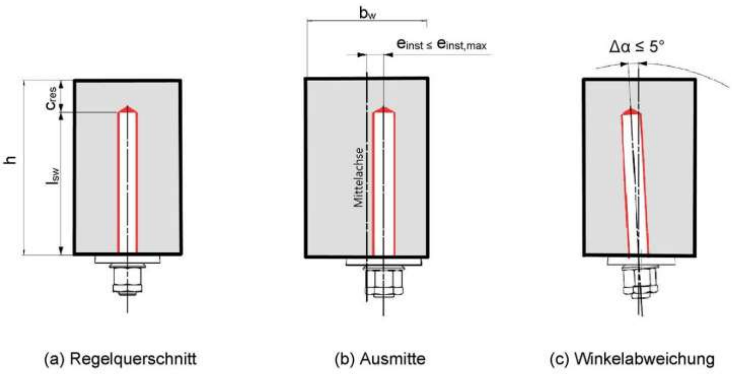


Fig. 7: Permissible installation tolerances (a) Regular cross section, (b) eccentricity and (c) deviation of angle

It should be noted that this eccentricity applies only to a single row of threaded rods, as a single eccentric tensile tie results in a torsional load on the member, which is proportional to the applied shear force.

Therefore, the following applies:

$$b_{w,eff} = b_w - \min\left(e_{inst}, 50\,mm, \frac{b_w}{6}\right) \quad (14)$$

The remaining parameters in the equation do not differ from DIN EN 1992-1-1/NA:

- Lever arm z=0.9d, with an upper limit of $z = max(d - 2c_{v,l}; d - c_{v,l} - 30\,mm)$. Here, $\boldsymbol{d}$ is the effective depth to the flexural reinforcement, and $\boldsymbol{c_{v,l}}$ is the concrete cover of the longitudinal reinforcement in the compression zone, as shown in Figure 8.

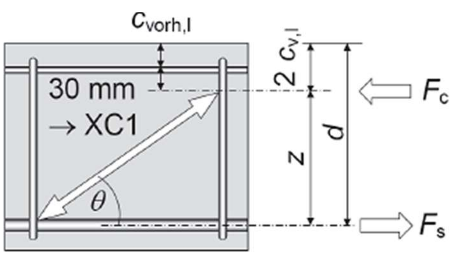


Fig. 8: Definition of the internal lever arm, z

- The dimensionless factor $\boldsymbol{\alpha_{cw}} = 1$, accounts for the stress state in the compression chord.
- The strength reduction factor for concrete subjected to shear, $\boldsymbol{v_1} = 0{,}75$.
- The design compressive strength of concrete, $\boldsymbol{f_{cd}} = \alpha_{cc} f_{ck}/\gamma_c$ where $\alpha_{cc} = 0{,}85$ and $\gamma_c = 1{,}5$
- The strut inclination angle $\boldsymbol{\theta}$ is limited by Equation (6.7aDE) in DIN EN 1992-1-1/NA:

$$1 \leq \cot\theta \leq \frac{1{,}2 + 1{,}4\sigma_{cp}/f_{cd}}{1 - \boldsymbol{V_{Rd,cc}}/V_{Ed}} \leq 3{,}0 \quad (15)$$

- In Eqn. (15), $V_{Rd,cc} = 0{,}5 \cdot 0{,}48 \cdot f_{ck}^{1/3}\left(1 - 1{,}2\frac{\sigma_{cp}}{f_{cd}}\right) \cdot \boldsymbol{b_{w,eff}} \cdot z,$ (16)

- For design according to DIN EN 1992-2/NA, the strut inclination angle is limited by Equation (6.107aDE):

$$1 \leq \cot\theta \leq \frac{1{,}2+1{,}4\sigma_{cp}/f_{cd}}{1-V_{Rd,cc}/V_{Ed}} \leq 1{,}75 \tag{17}$$

Since $V_{Ed} > V_{Rd,cc}$, the value of $\cot\theta > 3{,}0$ remains until a sufficiently large shear force $V_{Ed} \gg V_{Rd,cc}$ is reached, which reduces $\cot\theta < 3{,}0$. This newly calculated upper limit corresponds to the maximum inclination of the strut for members with minimum shear reinforcement and a correspondingly reduced strut resistance.

Figure 9 shows an example in which an increasing shear force raises the strut inclination angle according to Equation (6.7aDE) from DIN EN 1992-1-1/NA.

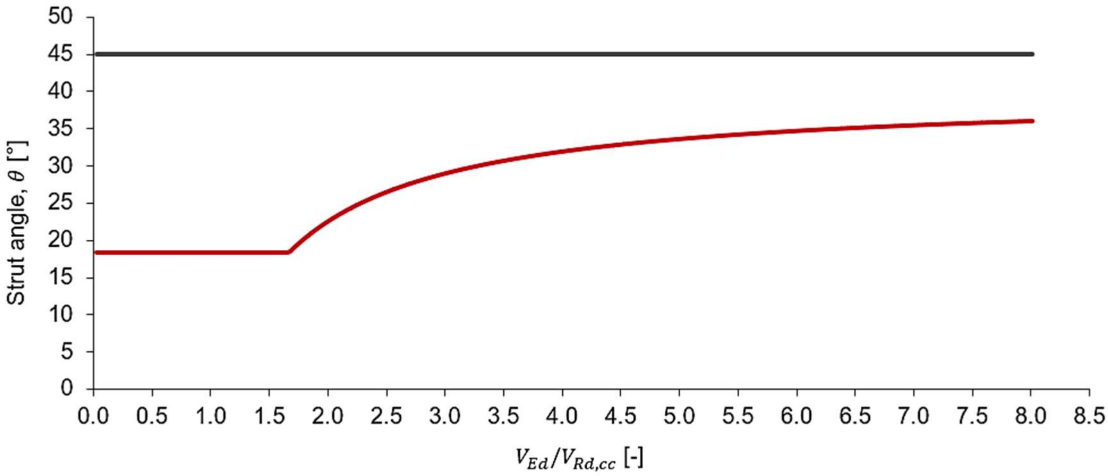


Fig. 9: Relationship between the ratio$V_{Ed}/V_{Rd,cc}$) and the calculated compression strut angle (the horizontal line at 45° represents the maximum compression strut angle).

7.2 Additional tensile force in the longitudinal reinforcement due to shear design

Although not explicitly required for verifying the strength of the steel or compression struts, the applied shear force V_{Ed}, according to EN 1992-1-1, Section 6.2.3 (7), generates an additional tensile force ΔF_{td} in the longitudinal reinforcement. This additional force increases as the inclination of the compression strut is reduced.

This force adds to the tensile force in the longitudinal reinforcement caused by bending and requires a separate verification to prevent yielding of the reinforcement or anchorage failure.

In new constructions, this verification for the additional tensile force can be omitted if the maximum bending moment $M_{Ed,max}$ of the concrete element has already been considered when designing the reinforcement and its anchorage.

7.3 Verification of Shear Reinforcement

With the post-installed HIT shear elements, which are installed orthogonally to the longitudinal axis of the concrete member, (i.e., the installation angle is α=90°) the resistance value is determined in accordance with DIN EN 1992-1-1/NA as follows:

$$V_{Rd,s} = \boldsymbol{k_{pi}} \cdot \boldsymbol{k_s} \cdot f_{ywd} \cdot \boldsymbol{a_{sw}} \cdot z \cdot \cot\theta \tag{18}$$

While the variables for the lever arm **z** and the compression strut angle $\boldsymbol{\theta}$ remain unchanged compared to the verification of the compression strut, the value for $\boldsymbol{f_{ywd}}$ is taken from the national approval and is 390 N/mm² for HIT shear elements made of both A4 stainless steel and 8.8 carbon steel.

The stressed cross-section of the retrofitted HIT-Shear elements, $\boldsymbol{a_{sw}}$, relative to the lengths of the concrete component, results from the combination of the following factors:

- Number of HIT-Shear elements in the transverse direction, $\boldsymbol{n_{swt}}$,
- Spacing of HIT-Shear elements in the longitudinal direction, $\boldsymbol{s_{wl}}$,
- Stressed cross-sectional area of each HIT-Shear element, $\boldsymbol{A_{sw}}$.

$$\text{Mit } a_{sw} = \frac{n_{swt} \cdot A_{sw}}{s_{wl}} \tag{19}$$

Material	Diameter	Design yield strength f_{ywd} [MPa]	Stressed cross section A_{sw}[mm²]
HAS 8.8, HAS-U 8.8, HAS A4, HAS-U A4	M12	390	84,3
	M16		157
	M20		245
	M24		353

Table 1: Geometric and material parameters for use in Equation (18) and (19).

Additionally, the approval includes two further coefficients, $\boldsymbol{k_s}$ and k_{pi}, that must be considered.

- A size-dependent coefficient $\boldsymbol{k_s}$ as a function of the lever arm **z** (in meters) for component thicknesses **h** between 200 and 2200 mm, where a larger lever arm reduces this coefficient (Eq. 20):

$$k_s = \begin{cases} 1{,}0 & if\ z \leq 0{,}75m \\ 1{,}15 - 0{,}20 \cdot z & if\ z > 0{,}75m \end{cases} \tag{20}$$

- The coefficient for retrofitted shear reinforcement, k_{pi}, which accounts for the following aspects:
    - Comparison of the effectiveness of HIT-Shear elements with that of cast-in-place stirrup reinforcement,
    - Consideration of the durability factor (long-term behavior), which accounts for the long-term effects on the bond strength of the mortar,
    - Influence of installation sensitivity and tolerances on performance,
    - Impact of flexural and shear cracks in the anchorage zone on the HIT-Shear elements in relation to the installation direction.

HIT Shear	Thread Size	Installation on tension side (Configuration A)	Installation on compression side (Configuration B)
Performance Parameter k_{pi}	M12	0,735	0,588
	M16		
	M20		
	M24		

Table 2: Performance parameter k_{pi}, which is used for the verification of the HIT Shear elements

Although the reinforcement system can be installed on both the tension and compression sides of a concrete component, it is important to distinguish between two applications. Figures 10 and 11 illustrate the two different configurations:

• Configuration A: Installation on the tension side of the component without the influence of flexural cracks on the ends of the HIT-Shear elements.

• Configuration B: Installation on the compression side of the component, where flexural cracks and shear cracks overlap in the anchorage zone of the HIT-Shear elements.

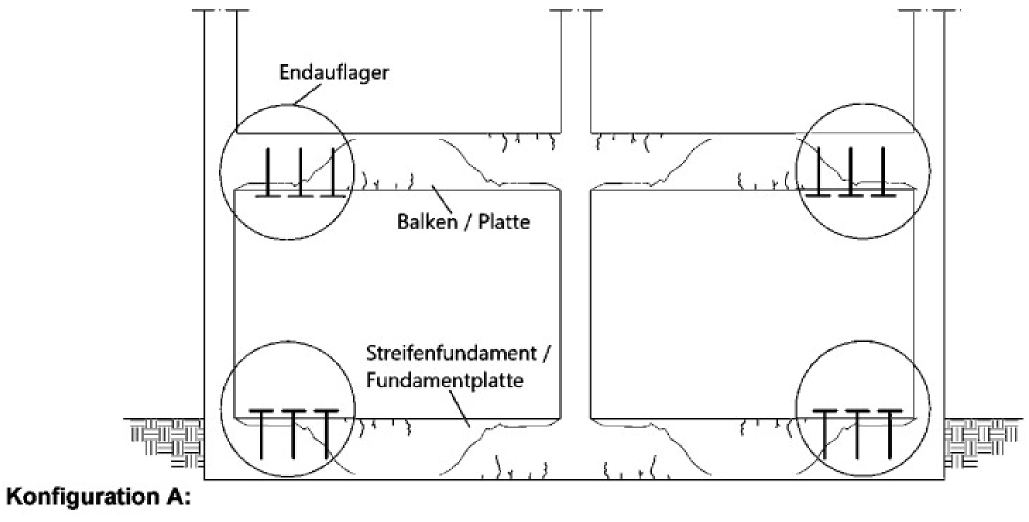


Fig. 10: Example of Configuration A, where the installation is performed on the tension side of the component, without the influence of flexural cracks in the anchorage zone.

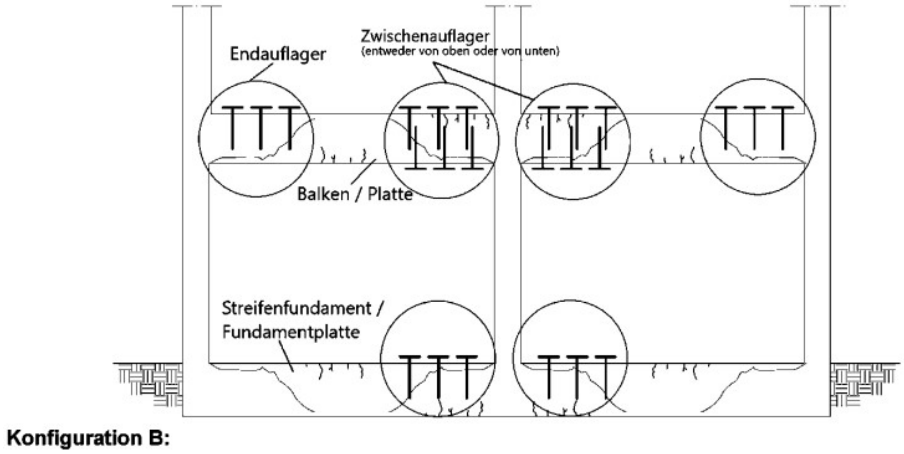


Fig 11: Example of Configuration B, where the installation is performed on the compression side of the component, with an overlap of flexural cracks and shear cracks in the anchorage zone.

7.4 Additional Requirements for the HIT Shear System

Installation Length / Anchorage Depth, l_{sw}

As shown in Equations (14) and (19) for the retrofitted shear reinforcement, the design model does not require explicit consideration of the installation length $\boldsymbol{l_{sw}}$ in the verification process, as it is a function of the component height $\boldsymbol{h}$ and the remaining concrete cover $\boldsymbol{c_{res}}$ (see Figure 12).

From an installation perspective, the remaining concrete cover prevents spalling or chipping of the concrete on the opposite side of the borehole.

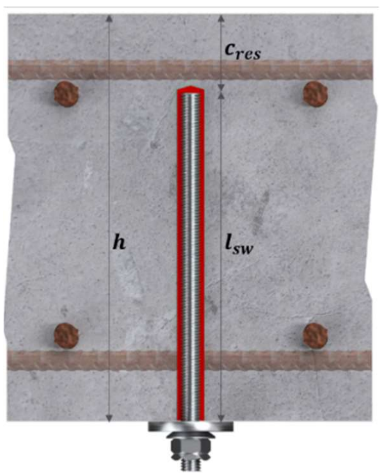


Fig.12: Simplified schematic representation of the installation, from [14]

From a design perspective, a fixed installation length ensures that the shear reinforcement is anchored in the compression chord of the component. This enables the formation of the truss model. As mentioned in Section 2 of this document, the truss model for shear design relies on the shear reinforcement enclosing or hooking into the compression chord to ensure force transfer at the nodes.

In this context, the combination of large-diameter reinforcement (e.g., M24 threaded rods) in thinner slabs (e.g., 200 mm) can lead to critical scenarios. In such cases, with a concrete cover $\boldsymbol{c_{res}}$ of 60 mm, the remaining installation length $\boldsymbol{l_{sw}}$ is only 140 mm, which is insufficient to effectively anchor the truss mechanism at the nodes.

Such combinations are therefore not permitted. It is necessary to establish a correlation between component height and reinforcement diameter, as described in Table 3 [14].

	Thread Size			
	M12	M16	M20	M24
Minimal member thickness, $\boldsymbol{h_{min}}$ [mm]	200	400	600	
$\boldsymbol{c_{res}}$ [mm]	35	40	45	60

Table 3: Correlation between the minimum component height, the remaining concrete cover, and the diameter of the reinforcement elements according to Table 3 from [14].

Minimum Spacings in Transverse and Longitudinal Direction, $\boldsymbol{s_{wl}}$

For retrofitted reinforcement, defined minimum spacings of the HIT-Shear elements are necessary to prevent splitting between the HIT-Shear elements and a potential reduction in the overall shear load-bearing capacity. Table 4 shows the minimum spacings in the longitudinal and transverse directions.

Thread Size	**Minimum Spacing in Transverse Direction, $\boldsymbol{s_{wl,min}}$ [mm]**	**Minimum Spacing in Longitudinal Direction, $\boldsymbol{s_{wl,min}}$ [mm]**
M12	120	120
M16	160	160
M20	200	200
M24	240	240

Table 4: Minimum center-to-center spacing for each strengthening element, reproduced from Table 11 of [14]

As shown in Table 5 and Table 6, the maximum spacings in the longitudinal and transverse directions comply with the requirements in DIN EN 1992-1-1/NA, Tables NA.9.1 and NA.9.2 for linear components, as well as NCI to 9.3.2 (4) for planar components, with $V_{Rd,max}$ used from Equation (1) without modifications.

Ratio of Shear Force to Compression Strut Resistance	**Maximum Spacing in Longitudinal Direction, $\boldsymbol{s_{wl,max}}$ [mm]**	**Maximum Spacing in Transverse Direction, $\boldsymbol{s_{wt,max}}$ [mm]**
$\boldsymbol{V_{Ed}/V_{Rd,max} \leq 0,3}$	$\min\,(0{,}7h;\ 300\ mm)$	$\min\,(h;\ 800\ mm)$
$\boldsymbol{0,3 < \frac{V_{Ed}}{V_{Rd,max}} \leq 0,6}$	$\min\,(0{,}5h;\ 300\ mm)$	$\min\,(h;\ 600\ mm)$
$\boldsymbol{\frac{V_{Ed}}{V_{Rd,max}} > 0,6}$	$\min\,(0{,}25h;\ 200\ mm)$	

Table 5: Maximum Center-to-Center Spacing in Linear Components (e.g., Beams), extracted from Tables NA.9.1 and NA.9.2 of [12].

Ratio of Shear Force to Compression Strut Resistance	Maximum Spacing in Longitudinal Direction, $s_{wl,max}$ [mm]	Maximum Spacing in Transverse Direction, $s_{wt,max}$ [mm]
$\boldsymbol{V_{Ed}/V_{Rd,max} \leq 0,3}$	$0{,}7h$	
$\boldsymbol{0,3 < \frac{V_{Ed}}{V_{Rd,max}} \leq 0,6}$	$0{,}5h$	h
$\boldsymbol{\frac{V_{Ed}}{V_{Rd,max}} > 0,6}$	$0{,}25h$	

Table 6: Maximum Center-to-Center Spacing in Planar Components (e.g., Slabs), as stated in NCI to 9.3.2 (4) of [12].

Edge Distance, c_{wt}

Defining a minimum distance between the reinforcement elements and any concrete edge reduces the risk of splitting. This minimum distance is considered in the ETA of the injection mortar ETA 20/0541 [11]. However, the minimum distance is increased by a percentage of the installation length to account for the maximum allowable inclination of the borehole (5°) perpendicular to the concrete surface, as shown in Table 7.

Drilling System	M	Minimum edge distance, $c_{wt,min}$ [mm]		Maximum edge distance, $c_{wt,max}$ [mm]	
		Without drilling aid	Drilling aid	Linear Component	Planar Component
Hammer drilling	M12	$45\ mm + 0{,}06 l_{sw}$	$45\ mm + 0{,}02 l_{sw}$	$175\ mm$	$\max\,(175\ mm;\ 0{,}5h$
	M16	$50\ mm + 0{,}06 l_{sw}$	$50\ mm + 0{,}02 l_{sw}$		
	M20	$55\ mm + 0{,}06 l_{sw}$	$55\ mm + 0{,}02 l_{sw}$	$250\ mm$	$\max\,(250\ mm;\ 0{,}5h$
	M24	$60\ mm + 0{,}06 l_{sw}$	$60\ mm + 0{,}02 l_{sw}$		
Compres-sed air drilling	M12 M16	$50\ mm + 0{,}08 l_{sw}$	$50\ mm + 0{,}02 l_{sw}$	$175\ mm$	$\max\,(175\ mm;\ 0{,}5h$
	M20	$55\ mm + 0{,}08 l_{sw}$	$55\ mm + 0{,}02 l_{sw}$	$250\ mm$	$\max\,(250\ mm;\ 0{,}5h$
	M24	$60\ mm + 0{,}08 l_{sw}$	$60\ mm + 0{,}02 l_{sw}$		

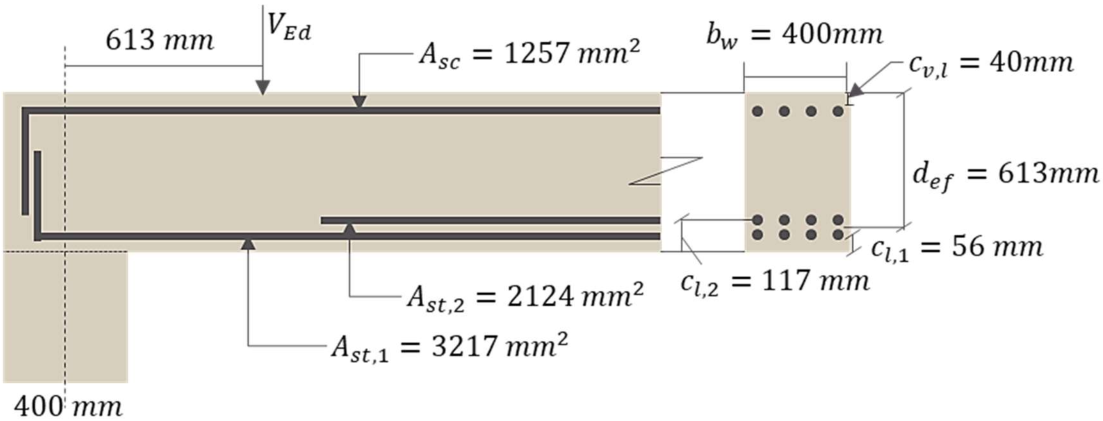
Table 7: Minimum and Maximum Edge Distances Based on Drilling Methods and Tolerances, Extracted from Table 14 of [14].

8. DESIGN EXAMPLE

An existing, simply supported beam with a cross section $b_w \times h = 400 \times 700\ mm$ of grade C30/37 spans 8.0 meters and is loaded by a uniformly distributed load of 130 kN/m at the ultimate limit state.

The concrete cover to both top and bottom longitudinal reinforcement is 40 mm, with the cross-sectional flexural steel, $A_{s,\mathrm{bottom}} = 4\ \pi \cdot 16^2 + 4\ \pi \cdot 13^2 = 5341\ \mathrm{mm}^2$ from 4H32 + 4H26 in two layers and $A_{s,\mathrm{top}} = 4\ \pi \cdot 10^2 = 1257\ \mathrm{mm}^2$ from 4T20 (B500B, $f_{sd} = f_{sk}/\gamma_s = 500/1.15 = 435\ \mathrm{N/mm}^2$).

The resistance of the existing member is verified per DIN EN1992-1-1/NA & strengthened per *aBG Z-15.5-383*.



Total ultimate load on the beam, $W_{\mathrm{tot}} = w_d\ L = 130\ \cdot 8.00\ = \mathbf{1040\ kN}$

Support reaction, $R = \frac{W_{\mathrm{tot}}}{2} = \frac{1040}{2} = \mathbf{520\ kN}$

Effective distance from the support edge: $d_v = H + d_{ef} = 400 + 613 = \mathbf{1013\ mm}$

Reference location to calculate the internal forces, $x = \frac{d_v}{2} = \frac{1013}{2} = \mathbf{506,5\ mm}$

6.2.1 (8) [8] Shear at distance x from the support edge, $V_{Ed,x} = R - w_d\ x = V_{Ed} = 520\ - (130 \cdot 0{,}613) = \mathbf{440}\ \boldsymbol{kN}$

6.2.1 (5) [8] Verification of existing section, $V_{Rd,c} \geq V_{Ed}$

Eq. 3.15 [12] Design Value of Compressive Strength, $f_{cd} = \frac{\alpha_{cc} f_{ck}}{\gamma_c} = \frac{0{,}85 \cdot 30}{1{,}5} = \mathbf{17}\ \boldsymbol{MPa}$

Eq. 6.2.a [8] Shear resistance of the existing section, $V_{Rd,c} = \left[C_{Rd,c} k (100 \rho_l f_{ck})^{\frac{1}{3}} + k_1 \sigma_{cp}\right] b_w d \geq V_{Rd,c,min}$

6.2.2 (1) [8] Longitudinal Reinforcement Ratio, $\rho_l = \frac{A_{sl}}{b_w d} = \frac{5341}{400 \cdot 613} = 0{,}0218 \geq \mathbf{0,02}$

6.2.2 (1) [8] Coefficient for Component Height, $k = 1 + \sqrt{200/613} = \mathbf{1,571} \leq 2{,}0$

NDP Zu 6.2.2 (1) [12] Minimum Design Value of Shear Stress (Interpolated $600\ mm < d \leq 800\ mm$),

$$v_{min} = \begin{cases} \frac{0{,}0525}{\gamma_c} k^{3/2} f_{ck}^{1/2} \text{ if } d \leq 600\ mm \\ \frac{0{,}0375}{\gamma_c} k^{3/2} f_{ck}^{1/2} \text{ if } d > 800\ mm \end{cases} = \frac{0{,}0515}{1{,}5} \cdot (1{,}571)^{\frac{3}{2}} \cdot (30)^{\frac{1}{2}} = \mathbf{0,371\ N/mm^2}$$

Eq. 6.2.b [8] Minimum Design Value of Shear Resistance,

$$V_{Rd,c,min} = v_{min} b_w d = 0{,}354 \cdot 400 \cdot 613 = \mathbf{90,8\ kN}$$

Design Value of the Transferable Shear Force Without HIT Shear,

$$V_{Rd,c} = \left[0{,}1 \cdot 1{,}571 \cdot (100 \cdot 0{,}02 \cdot 30)^{\frac{1}{3}}\right] 400 \cdot 613 = \mathbf{150,8\ kN}$$

$\therefore V_{Rd,c} \leq V_{Ed}$, Shear Reinforcement Required

6.2.1 (5) [8] Verification with Shear Reinforcement, $V_{Rd} = \min\,(V_{Rd,s}\,;\,V_{Rd,max}) \geq V_{Ed}$

NCI Zu 6.2.3 (1) [12] Lever arm, $z = \min\,(0{,}9 \cdot 644\,;\max(644 - 2 \cdot 40\,; 644 - 40 - 30) = \mathbf{574\ mm}$

NDP Zu 6.2.3 (2) [12] Compression Strut Angle: $1{,}0 \leq \cot\theta \leq \frac{1{,}2+1{,}4\sigma_{cp}/f_{cd}}{1-V_{Rd,cc}/V_{Ed}} \leq 3{,}0$

Eq. 6.7bDE [12] With $V_{Rd,cc} = 0{,}5 \cdot 0{,}48 \cdot f_{ck}^{\frac{1}{3}} \left(1 - 1{,}2\frac{\sigma_{cp}}{f_{cd}}\right) \cdot \boldsymbol{b_{w,eff}} \cdot z = 0{,}5 \cdot 0{,}48 \cdot \sqrt[3]{30} \cdot 400 \cdot 543 = \mathbf{162\ kN}$

Minimum Compression Strut Angle, $\theta = \cot^{-1}\left(\frac{1{,}2}{1-162/440}\right) = 27{,}77°$ (use $\boldsymbol{\theta} = \mathbf{30}°$ for design)

Eq. 2.1 [14] Compression Strut Load-Bearing Capacity, $V_{Rd,max} = \frac{1 \cdot 400 \cdot 543 \cdot 0{,}75 \cdot 17}{\cot(30)+\tan(30)} = \mathbf{1199,1\ kN}$

Eq. 6.17 [8] Additional Tensile Force Due to Shear Force, $\Delta F_{td} = 0{,}5 \cdot 440 \cdot \cot(30) = \mathbf{381\ kN}$

Assuming two rows of M16 $\boldsymbol{A_{sw}} = \mathbf{157\ mm^2}$ are installed at a spacing of 185 mm along the beam's length from the tension side, with $\boldsymbol{k_{pi}} = \mathbf{0,735}$, the required cross-sectional area of the retrofitted threaded rod, $\boldsymbol{a_{sw}}$, relative to the lengths of the concrete component is:

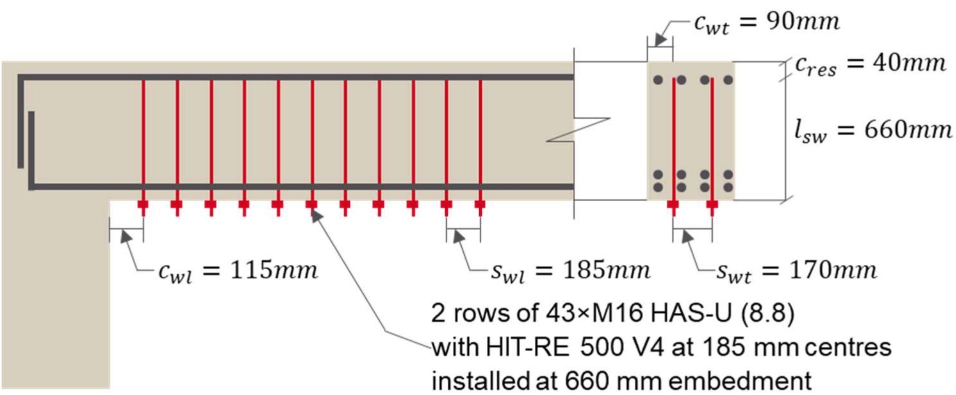
2.2.3 [14]

$$a_{sw} = \frac{n_{swt} \cdot A_{sw}}{s_{wl}} = \frac{2 \cdot 157}{185} \cdot 10^3 = \mathbf{1697,3\ mm^2/m}$$

Eq. 2.3 [14] Design value of the shear force capacity due to HIT-Shear:

$$V_{Rd,s} = k_{pi} \cdot k_s \cdot f_{ywd} \cdot a_{sw} \cdot z \cdot \cot\theta = 0{,}735 \cdot 1 \cdot 390 \cdot 1{,}6973 \cdot 543 \cdot \cot(30) = \mathbf{457,6\ kN} > 440\ kN$$

$\therefore V_{Rd} > V_{Ed}$, Ok!



Specification: Installation of 2 rows, each with 43 × M16 HAS-U 8.8 and HIT-RE 500 V4, spaced 185 mm along the beam's length, with an embedment depth of 660 mm and a spacing of 170 mm between the rows.

8.1 Optimization possibility

For a uniformly distributed load, as used in the above calculation example, the acting shear force V_{Ed} decreases in the central region of a structural element, effectively dividing the beam into three shear force zones. Table 8 summarizes the results of the same calculation procedure for the example above, but with a stepwise shear force distribution as shown in Figure 13, resulting in a reduction of the total number of required reinforcement elements from 86 pieces to 71 pieces.

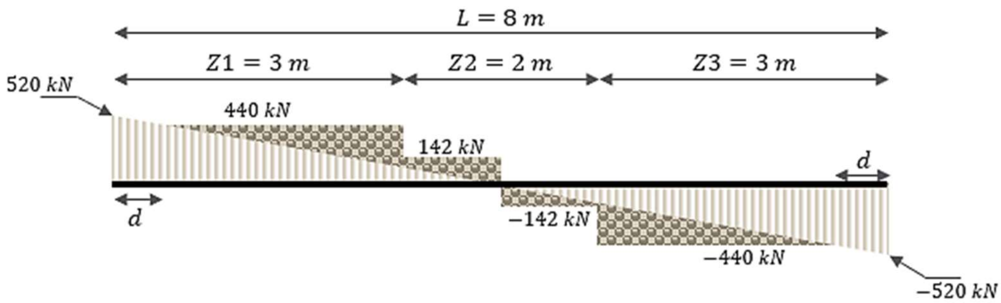


Fig 13: Shear force distribution after subdividing the beam into three zones (Zone 2 is a common zone with $V_{Ed} = \pm 142$ kN.

Zone	n_{wt} [-]	s_{wl} [mm]	θ [°]	a_{sw} [mm²/m]	$V_{Rd,max}$ [kN]	$V_{Rd,s}$ [kN]	No. of threaded rods
Z1	2	185	30	1697	1199,1	457.6	32
Z2	1	$s_{wl,max} = 300$	30	523	1199,1	149,1	7
Z3	2	185	30	1697	1199,1	457.6	32

Table 8: Design summary with three zones (the maximum spacing in Zone 2 does not exceed the limits specified in [12]).

9. DESIGN WITH THE “SHEAR REINFORCEMENT MODULE” FROM PROFIS ENGINEERING

When designing shear reinforcements, such as stirrups in concrete components, manually determining the number of reinforcement elements is often tedious and time-consuming due to the numerous possible combinations of diameter, spacing, and position.

Hilti's cloud-based PROFIS Engineering software offers a specially designed module for the analysis and reinforcement of concrete components with shear deficiencies. This module assists structural engineers in evaluating the load-bearing capacity of existing components and reinforcing them in a targeted manner to ensure a safe and efficient workflow.

The key advantages of the shear reinforcement module include:

• Selection of the appropriate beam-shaped or slab-shaped concrete component.

• Definition of, geometry, and material properties of the existing concrete component to assess the need for reinforcement under increased shear load.

• Subdivision of the component into zones to accurately allocate loads according to a stepped shear force diagram.

• Determination of the diameter and spacing of the reinforcement as well as the optimal angle of the compression strut.

• Automatic generation of the layout and calculation of the required reinforcement elements based on the defined inputs.

• Display of utilization ratios to verify the load-bearing capacity of the concrete, the steel strength of the reinforcement, and the maximum resistance of the compression strut.

• Generation of a comprehensive report with all calculation steps and detailed information on the reinforcement design for complete documentation.

With this module, PROFIS Engineering simplifies the planning and implementation of shear reinforcements, saves time, and ensures reliable results.

10. SUMMARY

Repurposing and reusing older structures offers numerous advantages compared to new construction, with each structure requiring the fulfillment of specific target specifications when reinforced. Depending on the chosen design philosophy, the structural engineer can address shear deficiencies in beam-shaped or slab-shaped concrete components in various ways—some of which are less invasive than others.

The use of post-installed shear reinforcement systems, such as Hilti's solution with HAS(-U) threaded rods and HIT-RE 500 V4 mortar (HIT-Shear elements), is an innovative example of a minimally invasive method that can significantly improve a component's shear capacity.

As a system that has been comprehensively tested and granted a general type approval (aBG) by the DIBt, this solution enables engineers to apply a familiar design approach based on Eurocode 2, which is integrated into Hilti's PROFIS Engineering Suite. By selecting the critical design parameters—diameter, spacing, and a variably inclined compression strut—engineers can develop an appropriate solution.

Thanks to an intuitive user interface, the new shear reinforcement module helps engineers to save time during the design phase, create added value for their clients, and contribute to a safer and more resilient built environment.

11. LITERATURE

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