CONCRETE OVERLAY

Design of the longitudinal Shear Strength of Concrete-to-concrete Interfaces acc. to EOTA TR066

The current European standard for the design of reinforced concrete structures EN 1992-1-1 (EC2) [1] contains rules for the design of the shear capacity of concrete/concrete joints of semi-precast concrete elements. However, for the design of reinforced interface with post-installed shear connectors EOTA TR 066 [2] is the appropriate design approach.

This article takes a comprehensive look at the topic of concrete overlay. It examines the current dimensioning regulation for overlay and deals with the individual load-bearing components that describe the load-bearing resistance of the interface of concrete overlay. In addition, information is given on the preparation of the interface surface and installation of the post-installed shear connectors on the basis of EOTA TR 066 [2]. Finally, solutions are shown how a design can be modelled and calculated as a whole. Here we refer to the concrete overlay module of the Hilti design software PROFIS Engineering.

Figure 1 A typical application of concrete overlay in civil engineering is the reinforcement or renovation of industrial flooring.

Content

1 Abstract

The installation of new, retrofitted concrete layers (concrete overlay) is becoming increasingly important due to the growing need for repair and reinforcement of existing structures.

Bridge cross-sections reinforced by a new concrete layer as well as the repair and reinforcement of existing concrete components by a new concrete layer are typical examples of the use of overlay, see Figure 2. If the shear stresses in the bonded joint between the concrete layers that were poured at different times are not sufficiently transferred, the structural safety is at risk.

a) Reinforcement or repair of industrial floors

b) Repair of a ceiling

c) Repair and reinforcement of a bridge deck

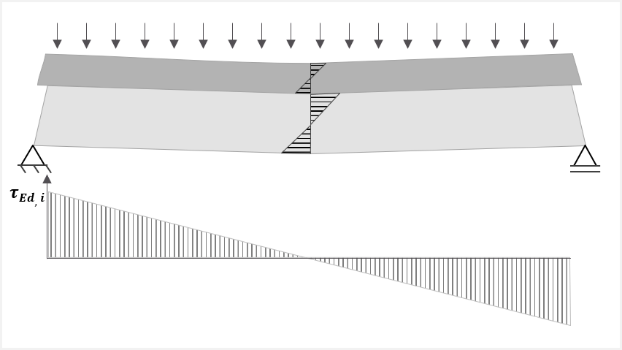
Figure 2 A typical application of concrete overlay in building construction and civil engineering

Figure 3a shows the stress state of a beam without the activation of shear stresses between the concrete layers (unreinforced interface). In this case, the concrete layers behave independently of each other.

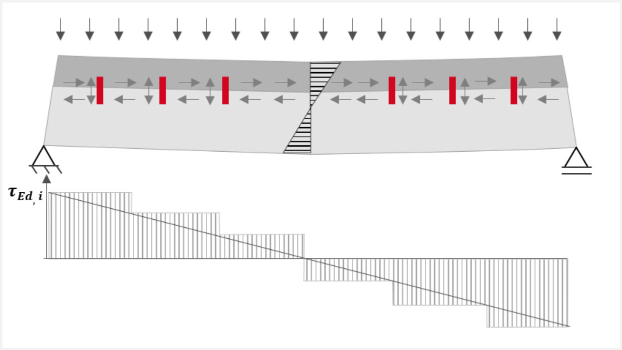
This is a simplification, because even in the case of an unreinforced interface, an adhesive bond acts between the concrete layers.

However, the adhesive bond is already impaired at relative deformations of 0.03 mm to 0.05 mm due to cracking between the interface.

In order to achieve a monolithic connection, post-installed shear connectors are usually placed. This allows, for example, bending compression and/or bending tension zones to be enlarged (structural reinforcement) or the original zone heights to be restored (refurbishment), see Figure 3b.



a) Without the activation of shear stress



b) With the activation of shear stress

Figure 3 Beam without and with activation of shear stresses in the interface

The new design concept according to EOTA TR 066 "Connector for strengthening of existing concrete structures by concrete overlay" [2] allows the design and dimensioning of these connections and the interface taking into account all load-bearing components (cohesion/friction, interlocking and dowel action) and other product-specific factors.

Thus, EOTA TR 066 [2] reflects the current state of the art in the design of overlay applications with post-installed shear connectors. This contrasts with EN 1992-1-1 (EC2) [1], which does not take into account the individual load-bearing behavior of post-installed shear connectors.

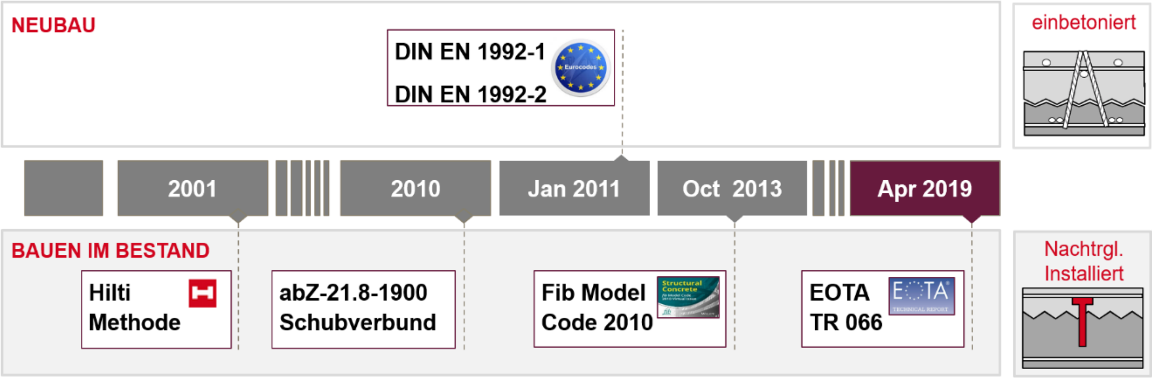


Figure 4 The "long way" of post-installed shear connectors to the final design according to EOTA TR 066 [2].

Figure 4 shows the "long way" from the design of post-installed shear connectors with the Hilti method (2001) to the general building inspectorate approvals (2010) to the "fib Model Code" 2010 [3] and finally the EOTA TR 066 [4] in 2019.

2 Implementation of concrete overlay application

The implementation of a construction measure with concrete overlay can be roughly simplified and divided into several work steps: The demolition or exposure of the existing, damaged concrete layer, the roughening of the surface, the installation of the post-installed shear connectors, the insertion of the new reinforcement and finally the placement of the new concrete layer (Fig. 5).

Before we describe the design approach of EOTA TR 066 [2], we provide some important advice on surface preparation and subsequent installation of shear connectors, as found in part in EOAT TR 066 [2].
Depending on the country, additional technical guidelines (e.g. ZTV-ING (Germany)), technical building regulations (e.g. EiT (EBA, Germany), technical manuals (e.g. Tunnel/ Geo-technik (Switzerland) or guidelines and regulations (e.g. RVS (Austria)) in conjunction with national guidelines and standards must be taken into account.

Demolition

Surface machining

Installation of the shear connectors

Laying the Reinforcement

Placement of the Concrete

Figure 5 Simplified overview of the execution steps of a construction measure with overlay

2.1 Preparation of the surface and installation of the post-installed shear connectors

Roughening of the surface is usually carried out by high-pressure water jetting. Other methods than high-pressure water jetting are not permitted, referencing on local or additional guidelines. This derives for example of Micro-cracks which can occur during roughening by milling and lead to damage of the concrete structure. Exposed aggregates that are well anchored in the concrete must be clearly visible [2]. The required average roughness depth R_t must correspond to the specified minimum value.

The average roughness depth itself can be determined according to the Kaufmann sand surface method or by means of an electronic, optical measurement [2]. The principle suitability of the roughened old concrete is to be checked by measuring the bond strength perpendicular to the interface (adhesive tensile strength) f_h, whereby at least the value of $f_h \geq$ min (1.5 N/mm²; f_{ctm}) must be achieved [2]. The scope of testing for the measurement of the roughness depth and the tensile strength shall be carried out in accordance with EOTA TR 066 [2], taking into account additional guidelines, building codes or regulations, whereby in particular for the measurement of the roughness depth the obviously least roughened areas shall be used.

2.1.1 Requirements for the cleanliness of the interface

The work sequence must be designed in such a way that the interface always remains clean from the time of roughening until the concrete is placed [2]. Tire abrasion and contamination of the surface must be avoided as far as possible. Special attention is be paid to the fact that the drilling dust must be extracted during the drilling process without exception [2]. If the surface is to be cleaned with compressed air, the air flow must be free of oil [2].

2.1.2 Post-treatment of the roughened surface

The clean interface must be kept moist for several days before placing the concrete. On the day of concreting, water puddles, regardless of their size, must be vacuumed [2]. At the time of concrete pouring, the surface must be slightly dry (silk matt) [2] to support the hydration of the fresh concrete in the area of the interface.

2.1.3 Post-installed shear connectors

There is a wide range of post-installed shear connectors available. A distinction can be made between concrete screw systems and mortar systems.
The installation of the shear connector type "concrete screw", e.g. Hilti HCC-HUS3, takes place in three steps. First, a hole is drilled in the existing concrete, ideally dust-free, using a hollow drill bit, e.g. Hilti Hollow Drill Bit. The standard hammer drilling method with corresponding ETA-compliant cleaning can also be carried out.

The ETA also describes installation situations where the borehole cleaning with Hilti shear connectors may be completely omitted. The concrete screw is driven in with a special impact screwdriver. The drilling depth is typically chosen slightly greater than the screw-in depth to create space for the dust and debris of the thread cutting process in the concrete.

The tensile load-bearing behavior of this system depends on the tolerance of the drilled hole, which is regulated in the ETA for the product. Due to the thread cut into the concrete, this shear connector is adjustable in height to a certain degree (Figure 6).

HCC-HAS-U HCC-K HCC-HUS3 HCC-B

Figure 6 Installation of Hilti HCC shear connectors with and without overlying reinforcement layer

The post-installed shear connectors of the "bonded anchor" type are special elements or standard elements equipped with additional accessories, e.g. HCC-B (special element, optimized for positioning the reinforcement and installation (Figure 6)), HCC-K (reinforcement bar with headed end (special element)) and HCC-HAS U (threaded rod with washer and nut (standard element)).

Regardless of the element, a borehole is drilled in the existing concrete and the drilling dust must be removed during drilling as described above. Therefore, Hilti offers the SAFEset technology, in which the dust is automatically extracted during the drilling process and the drill hole is additionally cleaned in compliance with ETA. The mortar is injected into the borehole with an automatic or pneumatic dispenser before the element is inserted into the borehole.

When using the HCC-B post-installed shear connector, on the other hand, the element can be automatically hammered into the drill hole before the mortar is injected. In this way, the Hilti HCC-B shear connector offers the possibility of injecting the mortar after the levelling measures through the unique hollow cross-section. Figure 7 provides an overview of the various Hilti shear connectors and their technical properties and range of applications.

	HCC-B	HCC-K	HCC-HAS U	HCC-HUS3
Belastungsart?	statisch + dynamisch	statisch	statisch	statisch, seismisch
Justierbarkeit Höhe?	nivellierbar über Rippen	nivellierbar über Länge	nivellierbar über Länge	nivellierbar
Belastbarkeit/Zeitpunkt?	sofort belastbar (1kN)	nach Aushärtung Mörtel	nach Aushärtung Mörtel	sofort belastbar
Durchmesser?	14	10, 12, 14, 16	8 bis 30	8, 10, 14
ETA?	ja (auch Ermüdung)	ja	ja	ja
Mörtel?	RE500 V4	RE500 V4, HY200-R V3	RE500 V4, HY200-R V3, HY170	nicht notwendig
Min. Dicke Bestandsbeton	127mm	100 mm (Ø =10mm)	100mm (Ø =10mm)	100mm (Ø =8mm)
Min. Dicke Aufbeton	≥75mm	≥ 42mm + c_{nom} (min h_{ef}, Ø =10mm)	≥ 44mm + c_{nom} (min h_{ef} , Ø =8mm)	≥ 48mm + c_{nom} (min $h_{ef,}$ Ø =8mm)

Figure 7 Overview of Hilti shear connectors HCC (Hilti Concrete Connector) and their technical properties for the design of the shear capacity of interface according to EOTA TR 066 [2].

3 Load-bearing behavior of the interface

The behavior of interface subjected to longitudinal shear stresses can be described using the shear-friction theory. It should be noted, however, that the term "shear-friction theory" may be misleading as it includes several different stages of development.

The original "shear-friction theory" assumes that the transmission mechanism of shear stresses in an interface that is simultaneously subjected to shear and compression forces is only ensured by friction. Generally, a simple sawtooth model is used to illustrate the basic principles of this theory (Figure 8).

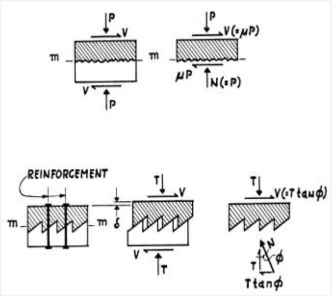


Figure 8 "Shear-friction theory" as sawtooth model 1960 by Birkeland and Birkeland [5].

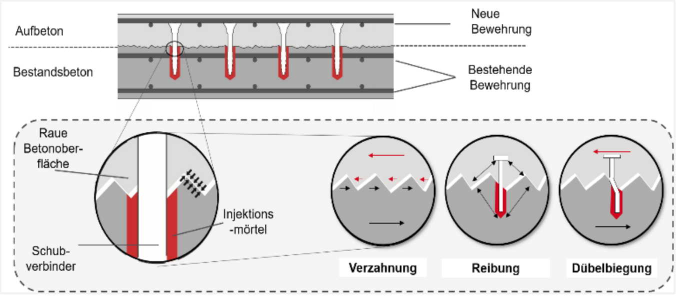


Figure 9 Shear transfer in the reinforced composite joint: cohesion / interlocking, friction and dowel effect using the example of the shear connector HCC-K.

This theory was developed around 1960 by Birkeland and Birkeland [5]. In 1972, it was extended by Mattock and Hawkins [6] to include the load-bearing component of cohesion. In 1978, concrete compressive strength was included in the theory as proposed by Loov [7]. Finally, Randl [8] describes that the shear transfer in the reinforced composite joint consists of three main mechanisms: cohesion, friction and dowel action. The three main mechanisms can be clearly described in Figure 9. Figure 10 shows the shear stress curve as a function of the relative displacement of the individual load-bearing mechanisms (adhesion/interlock τ_{adh}, friction τ_{sf} and shear reinforcement τ_{sr} (Zilch and Reinecke [9]).

The adhesion component τ_{adh} results from chemical adhesive bonds between the particles of the old and new concrete. When the maximum load-bearing capacity of the adhesive bond is reached, detachment occurs at the interface between the concrete layers and the shear stresses are transferred by mechanical interlocking due to surface roughness.

As the relative displacement between the concrete layers increases, the shear connectors crossing the interface are stressed and the shear connectors may fail by yielding of the steel, pullout failure or other possible failure modes. As a result of the resistance of the shear connectors, the interface is subjected to compression and the shear forces are transmitted by friction (τ_{sf}). Due to the relative displacement of the concrete layers, the post-installed shear connector is also subjected to shear force, which is usually referred to as dowel action (τ_{sr}).

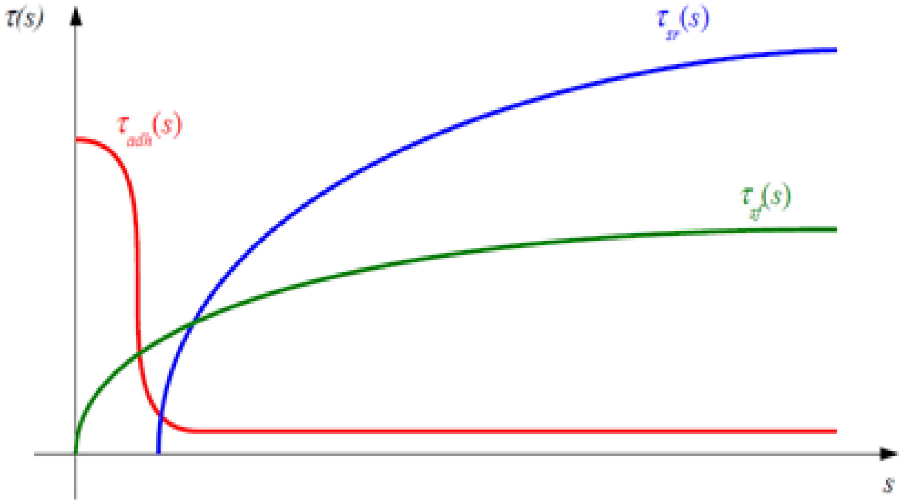


Figure 10 Shear stress curve as a function of relative displacement for the individual load-bearing mechanisms (adhesion/interlock τ_{adh}, friction τ_{sf} and shear reinforcement τ_{sr} (dowel action) (Zilch and Reinecke [9]).

With increasing surface roughness, the shear resistance and the shear stiffness of the composite joint increase considerably. In addition, the distribution of the total resistance between the three load-bearing components changes. In the extreme case, when the interface is very rough, the connectors at the joint are mainly subjected to tensile stress, whereas with a smooth interface the dowel stress on the connectors in shear is predominant.

4 Design of the shear joint according to EOTA TR 066

4.1 Impacts

4.1.1 Static and quasi-static action

4.1.1.1 External forces

To determine the acting shear stress, the applied external shear force $V_{Ed,i}$ is converted by the following equation into a shear stress $\tau_{Ed,i}$ acting parallel to the interface in a given section i:

[N/mm2]

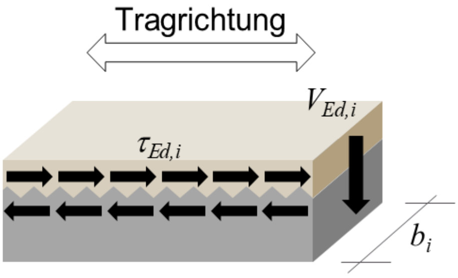


Figure 11 Conversion of the external shear force $V_{Ed,i}$ into a shear stress $\tau_{Ed,i}$ acting in parallel in the interface of the composite joint

β = ratio between the longitudinal force in the new concrete and the total longitudinal force in either the compression or tension zone, for the section under consideration, see Figure 12.

$V_{Ed,i}$ = acting external shear force

b_i = width of the zone under consideration

z = Lever arm of the internal forces

These areas or zones of length l_i can be defined based on the shear stress distribution due to external loading (shear force distribution), whereby the maximum shear stress within the zone is decisive. The ratio of the longitudinal forces related to the total longitudinal force b depends on the height of the new concrete layer related to the height of the concrete compression zone (positive bending moment, see Figure 12).

Where x is the height of the concrete compression area, $A_{s,N}$ is the cross-sectional area of the reinforcement in the new concrete layer, $A_{s,E}$ is the cross-sectional area of the reinforcement in the existing concrete, h_N is the height of the new concrete layer and h_E is the height of the existing concrete ("old").

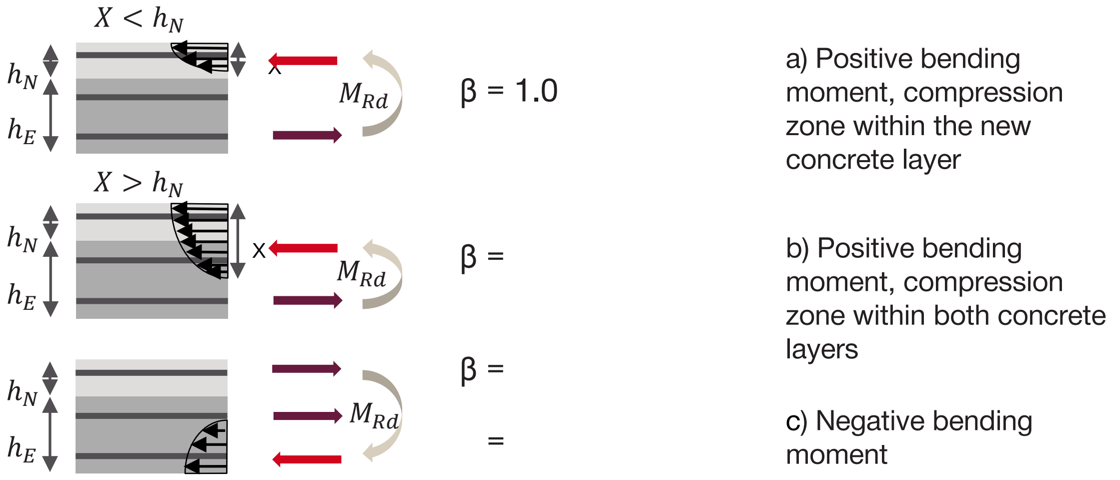


Figure 12 Determination of the ratio of the longitudinal force in the new concrete to the total longitudinal force (b) considering different boundary conditions

4.1.1.2 Forced forces

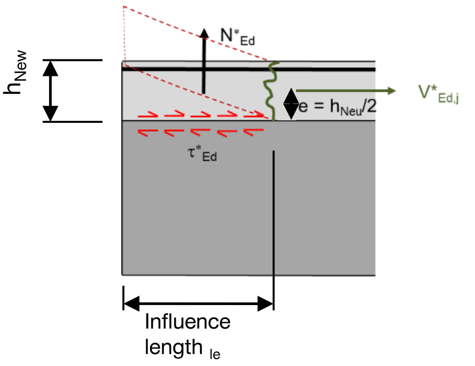


Figure 13 Lifting forces due to shrinkage according to EOTA TR066 [2], schematic

EOTA TR 066 [2] also considers constraint forces at the edge of the concrete layer due to shrinkage under static and quasi-static actions. This generates shear stresses parallel to the bond joint τ^*_{Ed} and uplift forces $N^*_{Ed,j}$ (Fig. 13). These uplift forces are considered within a certain influence length l_e along the edge area depending on the surface roughness and the height of the new concrete layer.

These must be smaller than the tensile resistance N_{Rd} of the shear connector taking into account the governing failure mode. The higher the new concrete layer and the rougher the concrete surface, the greater the length l_e that must be taken into account.

It should be noted that in EOTA TR 066 [2], the constraint forces are not superimposed with the acting forces from external loading, as the required verification is carried out separately by a verification against external loading and a verification against constraint forces. For the verification against constraint forces, either the shear stress from the constraint forces or the applied shear stress from external actions in the interface is taken into account, whereby the maximum value of the applied shear stress is decisive:(τ_{Ed}=max.($\tau_{Ed,i}$; τ^{*}_{Ed})).

4.1.2 Fatigue action

The fatigue resistance of materials or components is generally determined experimentally with cyclic loading tests in which a pure fatigue action is applied without static actions. In cases where actions consist of a combination of fatigue and static actions, it is necessary to take this into account as it has an influence on the fatigue strength of the composite joint. Consequently, EOTA TR 066 [2] categorizes the fatigue action that generates a cyclic load in the composite joint by 3 situations (Figure 14):

Situation 1

The acting cyclic shear stress $\Delta\tau_{Ed}$ is based on a fatigue action without static component (puls. action)).
The lower cyclic loading takes the value zero ($\Delta\tau_{Ed\,,min}$=0).

Situation 2

The applied cyclic shear stress $\Delta\tau_{Ed}$ is based on static action (pulsating action) and fatigue action.
The lower cycl. loading is greater than zero (($\Delta\tau_{Ed\,,min}$ >0).

Situation 3

The acting cyclic shear stress $\Delta\tau_{Ed}$ follows with changing signs.

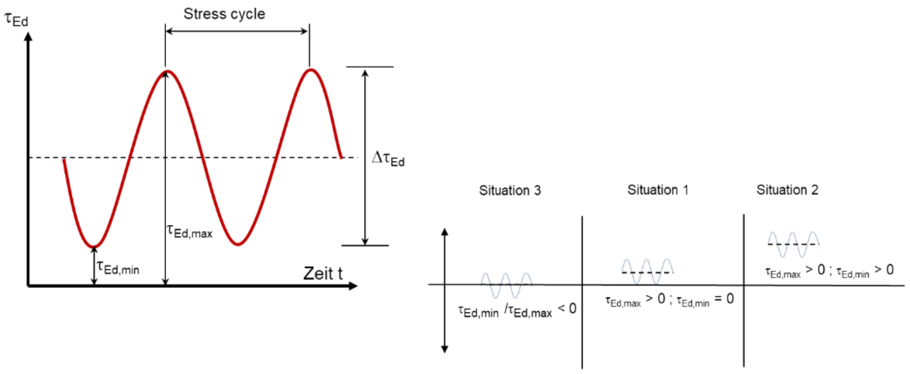


Figure 14 Designation and categorization of cyclic action according to EOTA TR 066

4.1.3 Seismic action

For the design under seismic action, the interface is designed for the maximum load that results from the load combinations with earthquake loads $V_{Ed,i,seis}$ according to EN 1998-1:2004 [10] in the ultimate limit state. Additional boundary conditions with regard to design as well as application-specific boundary conditions (slab, wall, beam, frame structure) of the reinforcement measure must be taken into account when determining the earthquake load acting on the reinforced interface.

4.2 Resistance of the shear joint

4.2.1 Static, quasi-static resistance

Two application conditions are defined for the calculation of the shear strength of the interface R_d

4.2.1.1 Shear capacity of the shear joint without shear connectors (rigid composite)

Application condition 1 applies to rigid bond without subsequently installed shear connectors, where a good bond can be assumed and no tensile stresses occur perpendicular to the shear joint. In this case, the design of the shear resistance of the interface is carried out via the adhesive bond (No.1 in Fig. 15) and friction due to external normal stresses (No.2 in Fig. 15) without considering shear connectors. The corresponding coefficients depend on the roughness of the joint and are given in EOTA TR 066 [2].

The shear strength is limited by the concrete compression strut (No. 3 in Fig. 15). The maximum shear strength of the bonded joint is approximately 30 % of the design value of the concrete's cylindrical compressive strength.

$$\tau_{Rd} = \underbrace{c_a \cdot f_{ctd}}_{①} + \underbrace{\mu \cdot \sigma_n}_{②} \leq \underbrace{0{,}5 \cdot \nu \cdot f_{cd}}_{③}$$

Figure 15 Application condition I: Shear capacity of the composite joint without shear connector (rigid composite)

If the condition $\tau_{Ed} \leq \tau_{Rd}$ is fulfilled, post-installed shear connectors are only required at the edge due to shrinkage (cf. chapter 4.1.1.2). If the condition $\tau_{Ed} \leq \tau_{Rd}$ is not fulfilled, post-installed shear connectors are required in the edge area along the interface.

4.2.1.2 Shear capacity of the interface with post-installed shear connector (reinforced interface)

Application condition 2 applies to non-rigid bond where relative displacement is allowed in the interface and post-installed shear connectors are used. Consequently, the design of the shear capacity of the interface includes the mechanisms of interlock (No. 1 in Fig. 16), friction (No. 2 in Fig. 16) and dowel action (No. 3 in Fig.16).

$$\tau_{\mathrm{Rd}} = \underbrace{c_r * f_{ck}^{\frac{1}{3}}}_{\text{① Verzahnung}} + \underbrace{\mu * (\sigma_n + \kappa_1 * \alpha_{\kappa 1} * \rho * \sigma_s)}_{\text{② Reibung}} + \underbrace{\kappa_2 * \alpha_{k2} * \rho * \sqrt{\frac{f_{y,k}}{\gamma_s} * \frac{0{,}85 * f_{ck}}{\gamma_c}}}_{\text{③ Dübelbiegung}} \leq \underbrace{\beta_c * \nu * \frac{0{,}85 \, * \, f_{ck}}{\gamma_c}}_{\text{④ Druckstrebe}}$$

Figure 16 Application condition II: Shear strength of the reinforced interface according to EOTA TR 066 [2].

Mechanical interlock not adhesion is described by the expression "$c_r \cdot f_{ck}^{1/3}$" in the case of an interface with shear connectors and takes into account the concrete compressive strength and the surface roughness. For a reinforced composite joint, the coefficient c_r takes values between 0 and 0.2. Note that compared to application condition 1, the bond resistance c_a is replaced by a coefficient for mechanical interlock c_r .

With increasing relative displacement of the concrete layers, the concrete layers want to separate further. The post-installed shear connectors counteract this separation and are subjected to tensile stress, causing compressive forces to develop between the surfaces, resulting in friction. In addition, the compressive forces can also be caused by external forces, which are taken into account by σ_N. However, the post-installed shear connectors can only be loaded up to the point where they fail in tension. The failure mode with the lowest resistance values determines the steel stress σ_S (Fig. 17).

The coefficient α_{k1} considers the percentage of the tensile force acting on the shear connector. For smooth surfaces $\alpha_{k1} = 0$. The dowel effect is caused by the relative displacement of both concrete layers. Under these conditions and depending on the value of the relative displacement, the shear connectors are subjected to shear stresses (in addition to tensile stresses due to friction) and bending stresses. As the load increases, the concrete near the surface within the interface is damaged so that the resultant of the resistance is redistributed deeper into the concrete. This increases the eccentricity between the shear force and the resultant compression at the shear connector, resulting in bending stresses in the shear connector. The factor α_{k2} takes this into account as the product-specific bending load capacity of the shear connector.

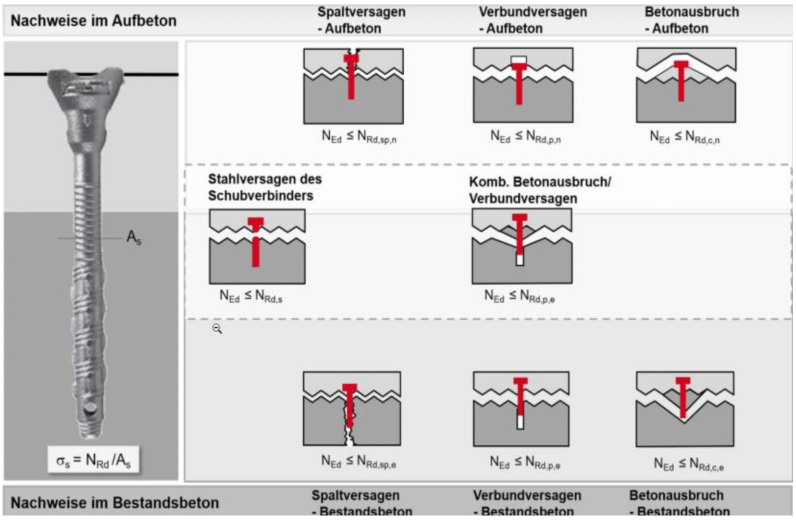


Figure 17 Specific resistance of the shear connector σs under tension depending on all possible failure modes

4.2.2 Fatigue resistance

The determination of the fatigue strength of the shear joint according to EOTA TR 066 [2] is based on several conditions. A fatigue proof is only possible if the surface is classified as very rough ($R_t \geq 3.0$mm), the new concrete layer has a concrete strength class of at least C40/50, while the existing concrete layer corresponds at least to concrete strength class C30/37.

If these boundary conditions are fulfilled, the shear resistance under fatigue loading can be determined by multiplying the resistance under static loading with a reduction factor η_{sc} and additional mathematical expressions depending on the classification of the fatigue loading, see section 4.1.2. The following example applies to the case of a pure fatigue loading (cf. fig. 4.1.2).

$\Delta\tau_{Rd} = \eta_{sc} \cdot \tau_{Rd}$ resp. $\Delta\tau_{Ed} \leq \eta_{sc} \cdot \tau_{Rd}$

For situations in which a fatigue-relevant action is superimposed with a static action, the reduction is carried out according to the Goodman diagram given in EOTA TR 066 [2]. The Goodman diagram takes into account the influence of a static load on the fatigue strength. Further details can be found in [2].

4.2.3 Seismic resistance

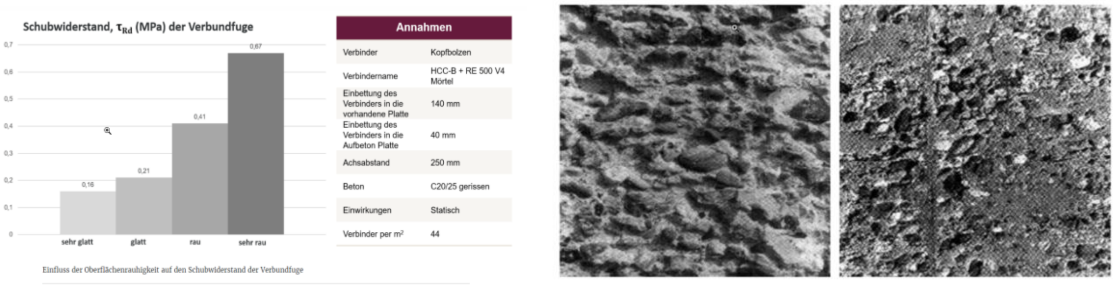
The determination of the seismic resistance of the composite joint is based on several boundary conditions. Unreinforced interface under seismic action are not covered by EOTA TR 066 [2], furthermore a very smooth surface is not allowed according to [2]. The design check of the post-installed shear connectors must be carried out depending on the seismicity and the significance class of the structure, see EN 1992-4 [11].

In addition, a relationship must be established between the governing failure mode and the desired behavior of the interface (ductile failure modes vs. brittle failure modes). The shear resistance under static action is described by the same parameters (but with different values) as under quasi-static action. In addition, the load-bearing component from cohesion/interlocking is neglected and the total shear resistance of the joint is further reduced by a product-dependent factor α_{seis}. This factor is specified in the product-related ETA. Further information on earthquake resistance can be found in [2].

5 A key parameter influencing the shear capacity of the composite joint: the roughness depth R_t

Figure 18a shows the shear resistance of a reinforced shear joint, calculated according to EOTA TR 066 [2], as a function of the classified surface roughness or roughness depth. The monolithic connection of the two concrete layers is executed with the Hilti post-installed shear connector HCC-B in combination with the Hilti injection system HIT-RE 500 V4.

The injection system and the shear connector are carrying the required assessment documents (ETA). Changing the joint classification from "smooth" to "rough" approximately doubles the shear resistance of the composite joint (0.21 N/mm² to 0.41 N/mm²). For the joint classification "very rough", the calculated shear resistance of the composite joint is more than four times the original shear resistance (very smooth).



Annahmen	
Verbinder	Kopfbolzen
Verbindername	HCC-B + RE 500 V4 Mörtel
Einbettung des Verbinders in die vorhandene Platte	140 mm
Einbettung des Verbinders in die Aufbeton Platte	40 mm
Achsabstand	250 mm
Beton	C20/25 gerissen
Einwirkungen	Statisch
Verbinder per m²	44

a) Shear resistance in the composite joint

b) Water jets 1500 bar = Rt= 3.3 mm (very rough)

c) Water jets 1500 bar = Rt = 0.8 mm (smooth)

Figure 18 Shear resistance of the reinforced composite joint as a function of surface roughness and different roughness depths with identical roughening methods (water jets)

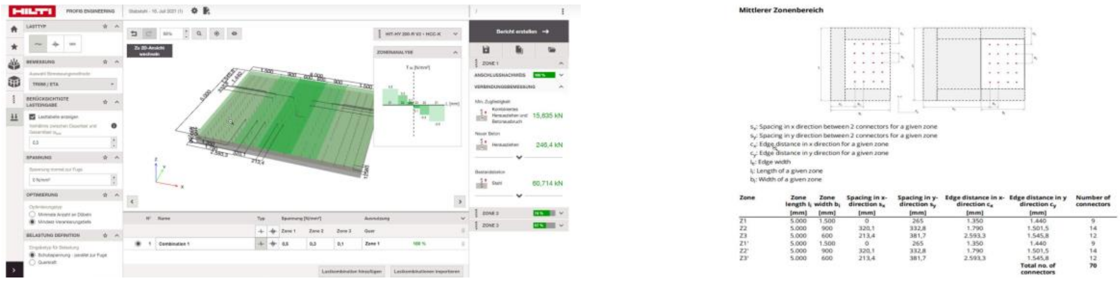
Furthermore, the verification of certain impacts requires a certain surface roughness or roughness depths. Unfortunately, the specification of the machining method is not necessarily sufficient to guarantee the required roughness depth. Figure 18a and 18b show the results in terms of measured roughness depth for identical roughening methods. Consequently, it can be said that not the method but the roughness depth R_t should be specified as the decisive parameter in the specification.

6 Practical design tips: the main differences between EN 1992-1-1 and EOTA TR 066

Not all post-installed shear connectors can be used for all edge conditions, see Figure 8. Selecting the right product may be considered as difficult. The easiest way to select the right product is to use the Hilti design software Hilti PROFIS Engineering in combination with the concrete overlay module which is available in the free standard as well as premium version.

In this software, the individual design requirements can be brought into the right context with the design requirements according to EOTA TR 066 [2] and the technically correct products. Furthermore, PROFIS Engineering offers the following additional advantages for the design of concrete overlay according to EOTA TR 066 [2]:

- PROFIS Engineering automatically optimizes your results. You decide whether you want to optimize your project with regard to the minimum number of post-installed shear connectors or their minimum embedment depth.
- PROFIS Engineering takes into account static actions, fatigue actions and seismic actions in accordance with EOTA TR 066 [2].
- PROFIS Engineering provides a clear and comprehensive design report and information on the position of the post-installed shear connectors in tabular form.



Mittlerer Zonenbereich

s_x: Spacing in x direction between 2 connectors for a given zone
s_y: Spacing in y direction between 2 connectors for a given zone
c_x: Edge distance in x direction for a given zone
c_y: Edge distance in y direction for a given zone
l_e: Edge width
l_i: Length of a given zone
b_i: Width of a given zone

Zone	Zone length l_i [mm]	Zone width b_i [mm]	Spacing in x-direction s_x [mm]	Spacing in y-direction s_y [mm]	Edge distance in x-direction c_x [mm]	Edge distance in y direction c_y [mm]	Number of connectors
Z1	5.000	1.500	0	265	1.350	1.440	9
Z2	5.000	900	320,1	332,8	1.790	1.501,5	14
Z3	5.000	600	213,4	381,7	2.593,3	1.545,8	12
Z1'	5.000	1.500	0	265	1.350	1.440	9
Z2'	5.000	900	320,1	332,8	1.790	1.501,5	14
Z3'	5.000	600	213,4	381,7	2.593,3	1.545,8	12
						Total no. of connectors	70

a) PROFIS Engineering, overlay Module

b) Design report (extract)

Figure 19 Implementation of EOTA TR 066 [2] in PROFIS Engineering

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While EN 1992-1-1 (EC2) [1] only considers cohesion, the external stresses and friction, the new EOTA TR 066 [2] also considers the dowel effect of the post-installed shear connectors.

This is necessary because in case of a relative displacement of the concrete layers, the stresses from both loading directions are superimposed in the shear connector and thus the usable axial tensile force is considerably reduced. This behavior depends on the product.

Furthermore, EN 1992-1-1 (EC2) [1] assumes a sufficiently anchored shear reinforcement, as it is known from semi-precast concrete elements, and for this reason steel yielding is considered as the decisive failure mode. In contrast, EOTA TR 066 [2] considers the individual failure modes of post-installed shear connectors. Consequently, the steel stress σ_s of the shear connector calculated from the design resistance under tension is used instead of the yield strength when applying the shear verification. The design resistance under tension is equal to the decisive resistance taking into account all possible failure types determined according to DIN EN 1992-4 [11]. These parameters are evaluated via the assessment document EAD 332347-00-0601 "Connectors for the reinforcement of existing concrete structures by means of concrete on top" and are mandatory to perform the design verification according to EOTA TR 066 [2].

In summary, EOTA TR 066 [2] represents a state of the art design concept for the design of shear joints (concrete overlay) with post-installed shear connectors.

7 Summary

EOTA TR 066 [2] is a state-of-the-art design concept for the design of the shear capacity of interface with post-installed shear connectors.

EOTA TR 066 [2] considers the three main load transfer mechanisms: cohesion/mechanical interlock, friction and dowel action under static action, quasi-static action, fatigue action and seismic action.

The load-bearing behavior of the post-installed shear connectors is product-specific and cannot be determined theoretically. It is determined in accordance with the European Assessment Document depending on the type of shear connector by EAD 330232-00-0601 (concrete screw as anchor), EAD 330499-00-0601 (bonded anchor as anchor) and EAD 332347-00-0601 (shear connector). Qualification as a fastening element or anchor is therefore not sufficient for a design according to EOTA TR 066.

Hilti offers the PROFIS Engineering Overlay Module to facilitate the design of overlay. In this software, the individual design requirements can be combined with the design requirements according to EOTA TR 066 [2] and the technically correct products.

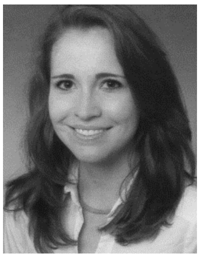
Authors:

Dr.-Ing. Jörg Appl

Senior Technical
Marketing Manager

Central Europe
Hilti Germany AG
Hilti Street 2

86916 Kaufering



Julia von der Warth

Product Manager
Engineering Software

Central Europe
Hilti Germany AG
Hilti Street 2

86916 Kaufering

Now that you have had a chance to read this article, we would like to know what you think about it.

Tell us what you liked, whether the article brought you closer to the topic, what you missed and anything else you can think of! Contact us directly via:

dr.joerg.appl@hilti.com

Sources

[1] DIN EN1992-1-1:2020-01 - Eurocode 2: Design of reinforced and prestressed concrete structures - Part 1-1: General design rules

[2] EOTA TR 066: EOTA Technical Report, Design and requirements for construction works of post-installed shear connection for two concrete layers, Amended 2020

[3] FIB ModelCode for Concrete Structures 2010

[4] EOTA TR 066: EOTA Technical Report, Design and requirements for construction works of post-installed shear connection for two concrete layers, April 2019.

[5] Birkeland, P.W. and Birkeland, H.W. - Connections in precast concrete construction, American Concrete Institute, Journal of the American Concrete Institute, Vol. 63, No. 3, pp. 345-368, March 1966.

[6] Mattock, A.H. and Hawkins, N.M. - Shear transfer in reinforced concrete - recent research, Precast/Prestressed Concrete Institute, PCI Journal, Vol. 17, No. 2, pp. 55-75, March-April 1972.

[7] Loov, R.E. - Design of precast connections, Paper presented at a seminar organized by Compa International Pte, Ltd, 8 p., Singapore, September 1978.

[8] Randl, N.: Investigation of force transmission between old and new concrete at different joint roughnesses. Innsbruck, Leopold-Franzens-University Innsbruck, Dissertation 1997

[9] Zilch, K. and Reinecke, R. - Capacity of shear joints between high-strength precast elements and normal-strength cast-in-place decks, FIB International Symposium on High Performance Concrete, Orlando, USA, 25-27 September 2000.

[10] DIN EN 1998-1: Eurocode 8: Design of structures for earthquake resistance - Part 1: Basic principles, seismic actions and rules for buildings; German version EN 1998-1:2004 + AC:2009

[11] DIN EN 1992-4: Eurocode 2 - Design of reinforced and prestressed concrete structures - Part 4: Design of anchorage of fixings in concrete, 2019-04