WHITE PAPER

HIT-FP 700 R: the next evolution of Hilti fire-resistant injectable mortar systems

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1. ABSTRACT

After several years of intense research and development, Hilti is introducing a new technology into the chemical mortar world: the “Hilti HIT-FP 700 R injection system”.

The HIT-FP 700 R is the first injectable two-component inorganic mortar system for post-installed rebar connections that holds an ETA 21-0624 according to the updated EAD 330087-02 [1] for cement-based mortars with improved fire resistance.

At 500°C, traditional post-installed rebar systems have no residual load capacity. By contrast, HIT-FP 700 R has been tested up to 500°C, keeping at least 2.3 N/mm2 of design bond strength $f_{bd,fi}$ under fire conditions (Figure 3-5).

Figure 1-1: Hilti HIT-FP 700 R injection system - foil pack

2. POST-INSTALLED REBAR APPLICATION ACCORDING TO EAD 330087

Since the mid-1970s, adhesive anchors have been used extensively in construction. Today, most projects require concrete-to-concrete installations, which are often secured by post-installed reinforcements that use chemical mortar.

Post-installed reinforcement utilizes deformed reinforcing bars which are placed in holes drilled in concrete and filled with injectable mortars. Post-installed reinforcing bars are typically used in concrete-to-concrete connections where new concrete is placed against existing concrete. As shown in Figure 2-1, the reinforcing bars are embedded in adhesive in a hole drilled into an existing concrete member and are cast in new concrete on the other side. While the portion of the reinforcing bars installed in existing concrete is straight, the portion embedded in new concrete can be straight or hooked. In contrast to steel-to-concrete anchoring applications, concrete-to-concrete connections using post-installed reinforcing bars often involve relatively small edge and corner distances and the bars are typically embedded as required to develop the tension yield strength of the reinforcing steel (e.g., EN 1992-1-1 [2]).

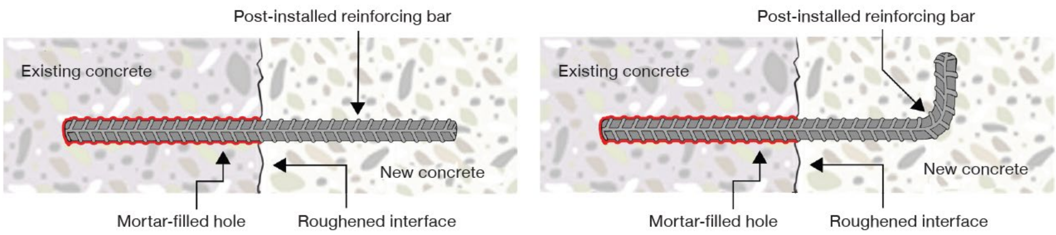


Figure 2-1: post-installed reinforcing using straight and hooked bars

The performance of post-installed reinforcing bars is strongly linked to the performance of the mortar and its robustness in different installation conditions (e.g. temperature, humidity) and can be very sensitive to jobsite/installation conditions (e.g. improper or incomplete borehole cleaning and/or injection, corrosive environment), loading conditions (e.g. freeze-thaw cycles, sustained loading at high temperature, cyclic seismic loading), the borehole drilling method, the quality and type of equipment used for installation, as well asthe depth and diameter of the application. All these considerations point to the necessity for appropriate product qualification requirements, helping to ensure that the behavior and performance of a post-installed reinforcing bar is similar to that of cast-in reinforcing.

Currently, the use of mortar systems for the realization of connections with post-installed reinforcing bars in Europe is limited to products evaluated according to the provisions established by the European Organisation for Technical Assessment (EOTA) in the European Assessment Document (EAD) 330087-02 [1] for static, seismic and fire loading conditions and EAD 332402-00-0601 [3] for post-Installed reinforcing bar (Rebar) connections with improved bond-splitting behavior under static loading (see Figure 2-2).

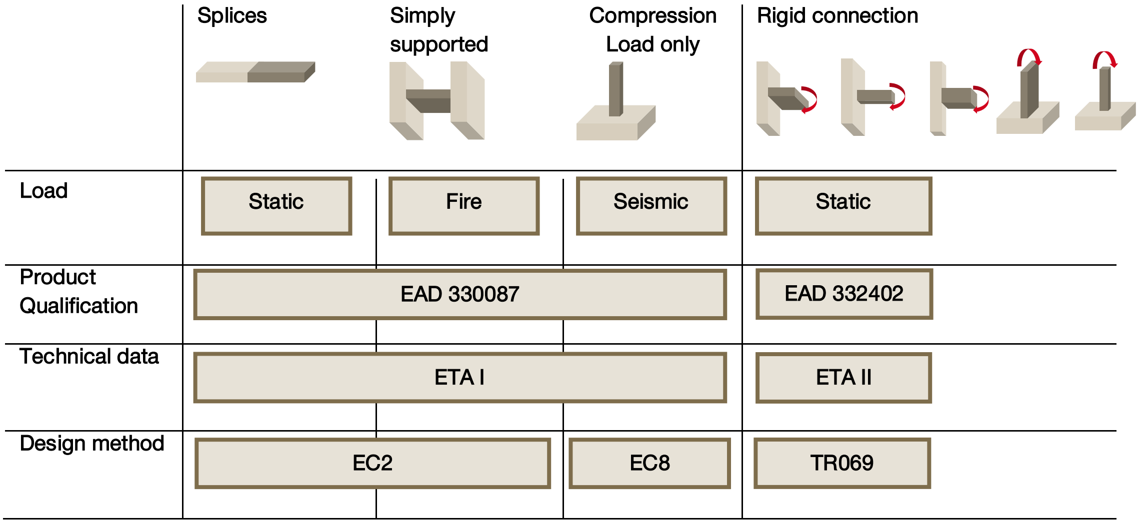


Figure 2-2: Overview of European regulatory framework for post-installed applications

Hilti provides a wide range of products (Fig. 2-3), such as HIT-RE500 V4 and HIT-HY 200-R V3, and is now introducing the new HIT-FP700 R injectable inorganic mortar for post-installed rebar connections.

	HIT-RE500 V4 	HIT-HY 200-R V3 	HIT FP 700 R 
Connection Type	Splices, simply supported, compression load only, moment resistant connections	Splices, simply supported, compression load only, moment resistant connections	Splices, simply supported, compression load only
Key features	High performance even in toughest conditions such as diamond drilling installation	High reliability and productivity for most rebar installations	First injectable inorganic mortar with fire performance up to 504°C
Approval	• ETA for rebar connections according to EAD 330087/EC2 for static, seismic and fire loading, 100y working life • ETA for rebar connections according to 332402/TR069 for static loading, 100y working life	• ETA for rebar connections according to EAD 330087/EC2 for static, seismic and fire loading, 100y working life • ETA for rebar connections according to 332402/TR069 for static loading, 100y working life	• ETA for rebar connections according to EAD 330087/EC2 for static and fire loading, 100y working life
Drilling Method	• Hammer drilling • Hammer drilling with SafeSet technology (Hilti hollow drill bit) • Diamond drilling • Diamond drilling in combination with Hilti Roughening tool	• Hammer drilling • Hammer drilling with SafeSet technology (Hilti hollow drill bit) • Diamond drilling in combination with Hilti Roughening tool	• Hammer drilling • Hammer drilling with SafeSet technology (Hilti hollow drill bit) • Diamond drilling in combination with Hilti Roughening tool
Drilled Hole cleaning	• Automatic hole cleaning (SafeSet) • Manual Cleaning • Compressed Air cleaning	• Automatic hole cleaning (SafeSet) • Manual Cleaning • Compressed Air cleaning	• Automatic hole cleaning (SafeSet) • Manual Cleaning • Compressed Air cleaning
Rebar diameter	8 mm – 40 mm	8 mm – 40 mm	8 mm – 40 mm
Max Temperature in the mortar	305°	268°	504°
At Installation temperature	-5 °C to +40 °C	-10 °C to +40 °C	+5 °C to +40 °C
In-Service temperature range	-40 °C to +80 °C	-40 °C to +80 °C	-40 °C to +160 °C
Working/curing time (at 20°C)	30 min / 420 min	15 min / 90 min	20 min / 10 days
Cartridge Volume	330 ml, 500 ml, 1400 ml	330 ml, 500 ml	490 ml

Figure 2-3: Overview of Hilti Ultimate mortars for post-installed rebar applications

The current article specifically examines post-installed rebar connections according to EN 1992-1-1, where the system holds an ETA according to EAD 330087-02 [1], with a main focus on the fire design. Some application examples are lap splices with existing reinforcement or anchorage of a reinforcement in a slab or foundation with existing cast-in bars (see Figure 2-4 to Figure 2-7).

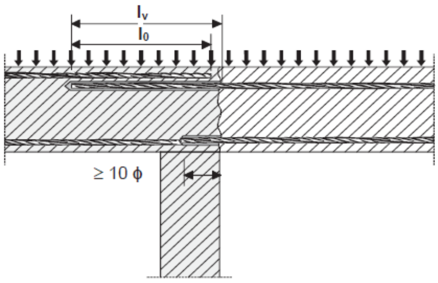


Figure 2-4: Overlap joint for rebar connections of slabs and beams, acc. to EAD 330087-02-0601 [1]

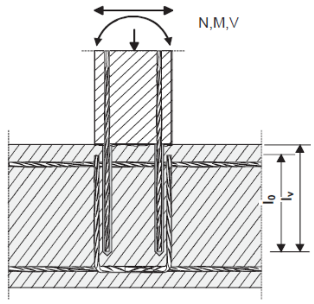


Figure 2-6: Overlap joint at a foundation of a column or wall where the rebar is stressed in tension, acc. to EAD 330087-02-0601 [1]

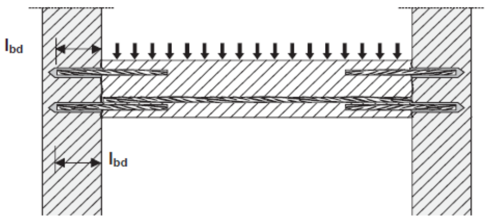


Figure 2-5: End anchoring of slabs or beams, designed as simply supported, acc. to EAD 330087-02-0601 [1]

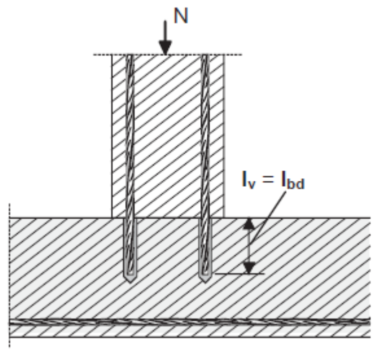


Figure 2-7: Rebar connection for components stressed primarily in compression, acc. to EAD 330087-02-0601 [1]

2.1 Why is fire design so important?

Fire is certainly a clear danger to any construction and needs to be prevented as a fire may occur anywhere and at any phase over the lifetime of a building, whether during construction or during service.

Insurance can compensate for the material damage caused by a fire, but it cannot protect against severe and irreparable consequences, such as loss of life or health or damage to the environment.

To increase fire protection and limit the spread of fire, ensuring evacuation routes and exits, the building should be divided into smaller fire sections by using fire-resistant elements, such as floor, walls, etc, (Figure 2-8).

When post-installed reinforcing bar connections are part of a fire-rated assembly (floor, roof, etc.), it is important that the fire resistance of the connection is evaluated using test data for the time-dependent reduction in bond strength associated with typical geometries and time-temperature loading protocols.

In general, these elements are designed and constructed to provide a specific period of fire load-bearing capacity resistance (R), typically rated for 30, 60, 90, 120, 180 or 240 minutes.

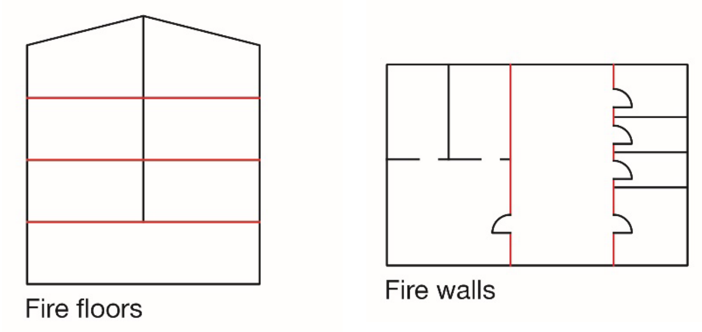


Figure 2-8: example of fire compartmentation

The post-installed connections involved in fire can be divided into two types:

1. Overlapping splices, such as slab-to-slab connections, where the surface is exposed to fire and the temperature along the anchorage length is constant and a function of the concrete cover and duration of fire (Figure 2-9).

2. Intersections, such as simply supported slab-to-wall connections, where the surface of the existing element and that of the new element is exposed and the temperature along the anchorage length is not constant (Figure 2-10).

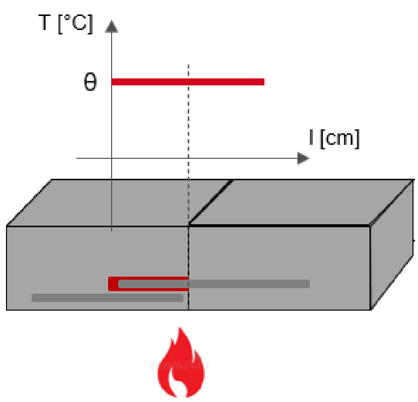


Figure 2-9: Typical temperature distribution of overlapping splices connections under fire

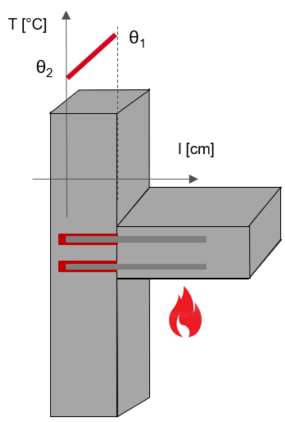


Figure 2-10: Typical temperature distribution of intersection connections under fire

The next chapter provides an overview on how fire performance is assessed and what are the main advantages of using HIT-FP 700 R under fire loading.

3. FIRE PERFORMANCE

3.1 Fire qualification

The qualification of post-installed rebar connections in fire conditions is covered by the European Assessment Document EAD 330087-02 [1], which is issued by EOTA and allows a design according to Eurocode 2 [2]. The assessment focuses on the bond strength behavior of the mortar in relation to temperature. The outcome of the assessment reflected in the European Technical Assessment is given in terms of temperature reduction factor $k_{fi}(\theta)$ and is used to calculate $f_{bd,fi}$ for equation 3.8 of Eurocode 2, part 1 (EN 1992-1-1) [2].

The reduction factor $k_{fi}(\theta)$ for the bond strength is derived through testing under simulated fire conditions. A constant load is applied to the rebar in a confined setup, while the temperature of the concrete specimen is increased according to a predefined heating rate. The temperature values are continuously measured in the borehole by means of two thermocouples. The temperature is increased until failure of the tested sample. With a minimum number of n=20 tested samples, and data points distributed in stress intervals smaller than 1 N/mm^2, a fitting curve for the data set of tensile bond strength as a function of the weighted average measured temperatures at failure is assessed. This curve is then translated into the reduction factor $k_{fi}(\theta)$ by calculating the ratio of the bond strength values to the reference value for cast-in-rebar for the respective concrete class.

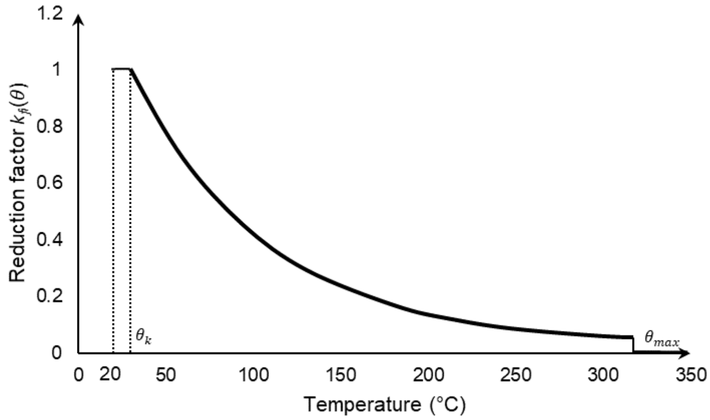


Figure 3-1. Example of the graph of reduction factor kfi (θ) for concrete strength class C20/25, from EAD 330087-02 [1]

Some additional requirements are introduced in the latest version of EAD 330087-02 [1] for the test series described above. These account for the particular behavior of cement-based mortars. For such systems, a lower sensitivity to fire conditions is expected in comparison with resin-based systems. Therefore, the qualification procedure considers the particular possibility that failure does not occur at fire-relevant temperatures and under certain applied loads.

The requirements for the testing protocol are thus adjusted in case this situation occurs or failure is not observed. The potential run out load level is confirmed with a total of three repetitions and the tests at lower loads may be omitted.

In addition, for mortars exhibiting a limited reduction in strength over temperature (e.g. cement-based mortars) it must be ensured that the assessed fire performance given in the ETA is limited to the cast-in rebar performance under fire, as given in Eurocode 2 [4].

$$f_{bd,PIR,fi}(\theta) = f_{bd,PIR} \cdot \frac{\gamma_c}{\gamma_{M,fi}} \cdot k_{fi}(\theta)$$

3.2 Fire design of post-installed rebar

The design of post-installed rebar connections can be carried out in accordance with Eurocode 2 [4], based on the performance characteristics of the mortar assessed following EAD 330087-02 [1].

This design path allows both a verification for the “cold” static loading condition and the fire loading condition. This chapter provides a description on how to achieve a fire design for post-installed rebar connections under fire conditions in compliance with Eurocode 2 [4] and in line with the given output from Hilti Software Profis Engineering (see Chapter 5).

The current provisions and the essential product characteristics needed as input for the verification of a connection system under fire are included in the European Technical Assessment of the relevant mortar, in the European Assessment Document EAD 330087-02 [1] and in the Eurocode 2 (EN 1992-1-1

[2] and EN 1992-1-2 [4]). In particular, the ETA of the product provides the values of design bond stress in relation to the temperature. An example is given in Figure 3-2.

Essential characteristics under fire exposure

Design value of the bond strength $f_{bd,fi}$ for a working life of 50 years and design value of the bond strength $f_{bd,fi,100y}$ for a working life of 100 years under fire exposure for concrete classes C12/15 to C50/60 for all drilling techniques.
The design values of the bond strength $f_{bd,fi}$ and $f_{bd,fi,100y}$ under fire exposure have to be calculated by the following equation:

$$f_{bd,fi} = k_{b,fi}(\theta) \cdot f_{bd,PIR} \cdot \frac{\gamma_c}{\gamma_{M,fi}}$$ for a working life of 50 years

$$f_{bd,fi,100y} = k_{b,fi,100y}(\theta) \cdot f_{bd,PIR,100y} \cdot \frac{\gamma_c}{\gamma_{M,fi}}$$ for a working life of 100 years

with

$$k_{b,fi}(\theta) = \frac{-0{,}0038 \cdot \theta + 8{,}6867}{f_{bd,PIR} \cdot 4{,}3} \leq 1{,}0$$ for a working life of 50 years

$$k_{b,fi,100y}(\theta) = \frac{-0{,}0038 \cdot \theta + 8{,}6867}{f_{bd,PIR,100y} \cdot 4{,}3} \leq 1{,}0$$ for a working life of 100 years

$\theta = \theta_{max}$ $\quad k_{b,fi}(\theta) = k_{b,fi,100y}(\theta) = 0{,}0$

$\theta_{max} = 504°C$

$f_{bd,fi}$	Design value of the bond strength in case of fire in N/mm² for a working life of 50 years.
$f_{bd,fi,100y}$	Design value of the bond strength in case of fire in N/mm² for a working life of 100 years.
(θ)	Temperature in °C in the mortar layer.
θ_{max}	Temperature in °C at which the mortar can no longer transfer bond stresses
$k_{b,fi}(\theta)$	Reduction factor under fire exposure for a working life of 50 years.
$k_{b,fi,100y}(\theta)$	Reduction factor under fire exposure for a working life of 100 years.
$f_{bd,PIR}$	Design value of the bond strength in N/mm² in cold condition according to Table C3 or Table C6 considering the concrete classes, the rebar diameter, the drilling method and the bond conditions according to EN 1992-1-1 for a working life of 50 years.
$f_{bd,PIR,100y}$	Design value of the bond strength in N/mm² in cold condition according to Table C3 or Table C6 considering the concrete classes, the rebar diameter, the drilling method and the bond conditions according to EN 1992-1-1 for a working life of 100 years.
γ_c	Partial factor according to EN 1992-1-1.
$\gamma_{M,fi}$	Partial factor according to EN 1992-1-2.

For evidence under fire exposure the anchorage length shall be calculated according to EN 1992-1-1:2004+AC:2010 Equation 8.3 using the temperature-dependent bond strength $f_{bd,fi}$.

Figure 3-2. Example of essential characteristics for fire conditions given in the ETA 21-0624 released dated 17/06/2022.

In the EAD 330087-02 [1], instructions are given to calculate the anchorage length in accordance with equation (8.3), using the design bond strength as a function of the temperature. This value is derived by considering the temperature reduction factor limited by 1.0 and the maximum temperature θ_{max}, in accordance with the following equation.

$$f_{bd,PIR,fi}(\theta) = f_{bd,PIR} \cdot \frac{\gamma_c}{\gamma_{M,fi}} \cdot k_{fi}(\theta)$$

where

$f_{bd,PIR}$ = design value of the bond resistance in cold condition

γ_c = partial safety factor according to EN 1992-1-1 [2]

$\gamma_{M,fi}$ = partial safety factor according to EN 1992-1-2 [4]

$k_{fi}(\theta)$ = temperature reduction factor assessed according to EAD 330087-02 [1]

f_{bd} = design value of ultimate bond stress for cast-in rebars in the various concrete classes according to EN 1992-1-1 [2] and EAD 330087-02 [1]

According to EN 1992-1-2 [4], for reinforced concrete structures in fire conditions given by ISO 834 [5], the temperature over the embedment length of a post-installed rebar will vary based on time and distance from the exposed element surface, which is related to a specific geometrical configuration and the relevant sides of fire attack. Temperature profiles are then identified for various application cases, as given in EN 1992-1-2 [4], annex A, for each fire requirement expressed in terms of time resistance (e.g., R30, R60, R90, R120).

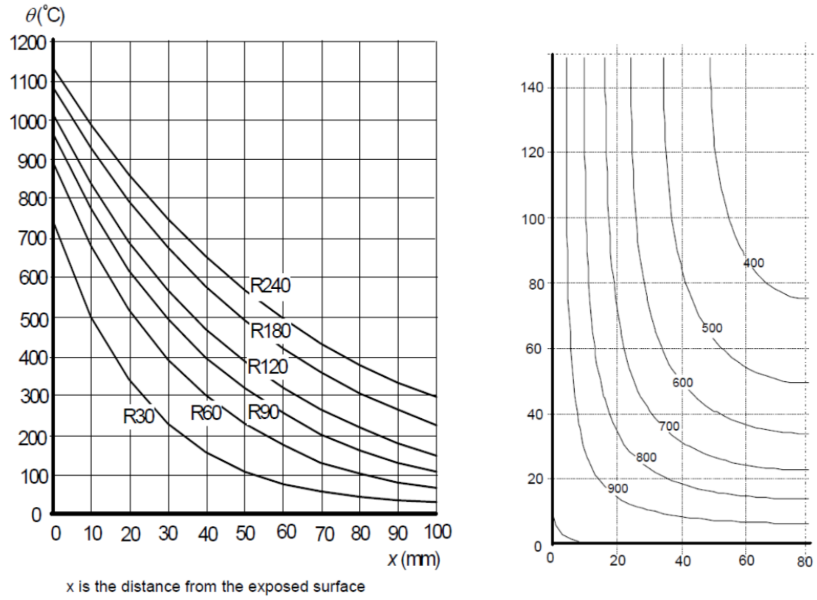


Figure 3-3. Example of temperature profiles for slabs with height h = 200 mm, from EN 1992-1-2, annex A, figure A.2 (left) [4]. Example of temperature profiles for a beam, h x b = 300 x 160 mm with fire requirement R90, from EN 1992-1-2, annex A, figure A.4 (right) [4].

Therefore, the common practice and state-of-the-art for the determination of the overall rebar bond stress to be used in equation (8.3) of EN 1992-1 [2] is to apply the so called Resistance Integration Method introduced in literature (Lahouar et al., 2018 [6]). The method requires a subdivision of the overall embedment length into shorter segments, each one having a different temperature according to the temperature profiles mentioned above and, therefore, a different contribution of bond stress associated with that temperature. The equivalent characteristic fire resistance of the connection is considered to be equal to the sum of the resistance values calculated in each segment.

For representative reasons, the segment length Δx shall be smaller than $2 \cdot d$ and is generally taken around 10 mm. The mean temperature along the segment is considered to derive the bond resistance in that length.

Hence, in case of fire, the equation (8.3) of EN 1992-1-1 [2] has to be adjusted as follows.

$$l_{b,rqd,fi} = (\emptyset/4)\left(\sigma_{sd,fi}/f_{bd,PIR,fi}\right)$$

Furthermore, the design anchorage length is given in equation (8.4) of EN 1992-1-1 [2], as follows.

$$l_{bd,fi} = \alpha_1 \cdot \alpha_2 \cdot \alpha_3 \cdot \alpha_4 \cdot \alpha_5 \cdot l_{b,rqd,fi} \geq l_{b,min}$$

For the design lap length calculation, section 8.7.3 of EN 1992-1-1 [2] applies, and the value is derived as follows.

$$l_{0,fi} = \alpha_1 \cdot \alpha_2 \cdot \alpha_3 \cdot \alpha_5 \cdot \alpha_6 \cdot l_{b,rqd,fi} \geq l_{0,min}$$

3.3 Performance of HIT-FP 700 R

The new inorganic injection system can withstand high temperatures as shown in the long-term (100 °C) and short-term (160 °C) temperature classes for standard applications as given in the ETA-21/0624 (see Figure 3-4).

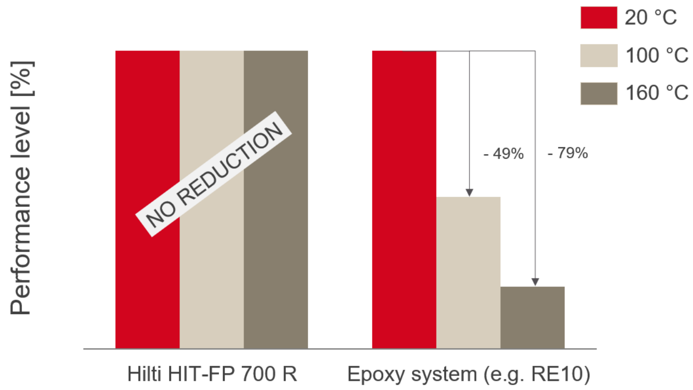


Figure 3-4. Performance level at 100°C and 160°C

In case of fire, the new resistance must also consider the used materials of the anchorage. These include the elongation and expansion of the steel at high temperatures as well as the heat-specific concrete capacity. Figure 3-5 shows the comparison between the Hilti HIT-FP 700 R, the organic materials and the concrete compressive capacity under fire.

For concrete class C20/25 and rebar diameter with $f_{bd,PIR}$ = 2.3 N/mm2 at 504°C, HIT-FP 700 R keeps 2.3 N/mm2 of design bond strength $f_{bd,fi}$ under fire conditions (considering γ_c= 1.5 and $\gamma_{M,fi}$= 1)

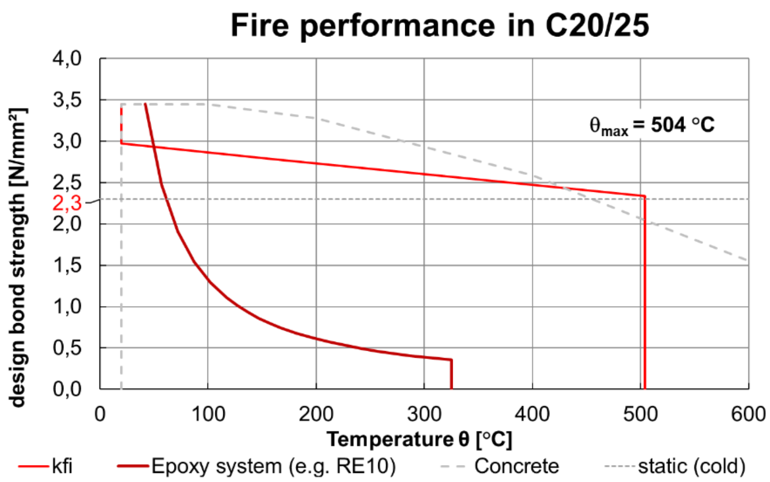


Figure 3-5. Graph of reduction factor kfi (θ) and design bond strength in fire conditions of HIT-FP 700 R for concrete strength class C20/25, compared to epoxy system and concrete

3.4 Performance comparison for cold and fire design

This section compares the performance of the new Hilti HIT-FP 700 R mortar in cold and fire design for the types of connections described in chapter 2.1, Figure 2-9 and Figure 2-10.

In the overlapping splices, such as slab-to-slab connections (see first column of Figure 3-6), HIT-FP 700 R gives the solution with the shortest required embedment length in fire conditions, already considering R30 requirement.

In intersection connections, such as slab to wall (see second column of Figure 3-6), the comparison of the mortars show less differentiation. On the other hand, for a connection such as beam to column, where the fire is four-sided, HIT-FP 700 R gives again the solution with the shortest embedment length in fire conditions, such as R30 (see third column of Figure 3-6)

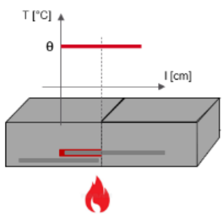
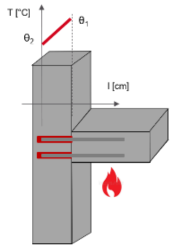
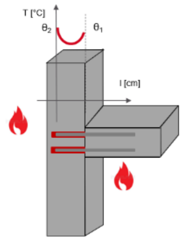
C20/25; Φ12@200 mm c = 40mm considering bar at yielding f_{yd} = 435 N/mm2 f_{yd,fi^*} = 0.7*435 = 305 N/mm			
$f_{yd,fi}$ is considered applying a reduction factor η_{fi} = 0.7 (EN 1992-1-2 2.4.2 (2) [4]*) , for a more detailed design please check EN 1992-1-2* [4]			
	SLAB TO SLAB	SLAB TO WALL	BEAM TO COLOUMN
Fire duration	Temperature range	Temperature range	Temperature range
R30	*T~ 150°C*	*T1~100° T2~20°*	*T1~200°C T2~230°*
Hilti HIT-RE 500 V4 	$f_{bd,pi}$ = 2.3 N/mm^2 $l_{bd,rqd,pi}$= 567 mm $f_{bd,pi,R30}$ = 0.85 N/mm^2 **$l_{bd,rqd,pi,R30}$= 1075 mm**	$f_{bd,pi}$ = 2.3 N/mm^2 **$l_{bd,rqd,pi}$ = 567 mm** $l_{bd,rqd,pi,R30}$= 290 mm	$f_{bd,pi}$ = 2.3 N/mm^2 $l_{bd,rqd,pi}$ = 567 mm **$l_{bd,rqd,pi,R30}$= 1380 mm**
Hilti HIT-HY 200-R V3 	$f_{bd,pi}$ = 2.3 N/mm^2 $l_{bd,rqd,pi}$= 567 mm $f_{bd,pi,R30}$ = 1.22 N/mm^2 **$l_{bd,rqd,pi,R30}$= 750 mm**	$f_{bd,pi}$ = 2.3 N/mm^2 **$l_{bd,rqd,pi}$ = 567 mm** $l_{bd,rqd,pi,R30}$= 270m mm	$f_{bd,pi}$ = 2.3 N/mm^2 $l_{bd,rqd,pi}$ = 567 mm **$l_{bd,rqd,pi,R30}$= 1060 mm**
Hilti HIT-FP 700 R 	$f_{bd,pi}$ = 2.3 N/mm^2 **$l_{bd,rqd,pi}$= 567 mm** $f_{bd,pi,R30}$ = 2.83 N/mm2 $l_{bd,rqd,pi,R30}$= 323 mm	$f_{bd,pi}$ = 2.3 N/mm^2 **$l_{bd,rqd,pi}$ = 567 mm** $l_{bd,rqd,pi,R30}$= 320 mm	$f_{bd,pi}$ = 2.3 N/mm^2 **$l_{bd,rqd,pi}$ = 567 mm** $l_{bd,rqd,pi,R30}$= 330 mm

Figure 3-6 – Performance comparison in fire conditions

4. UNDERSTANDING HIT-FP 700 R

HIT-FP 700 R is not simply an additional injectable system: it is a new technology. HIT-FP 700 R is the only injectable cement-based mortar which can be stored for 12 months as paste yet and it is also the only chemical mortar with high performance under fire and no creep behavior at high temperatures.

The HIT-FP 700 R technology enables a new chapter in the qualification of injectable chemical mortars for which an update of the previous EAD 330087-01 [1] was needed (see paragraph 4.3).

A further characteristic is the dispensing force: compared to commonly used resin based injection systems, HIT-FP 700 R has low dispensing forces at all allowed temperature ranges that, along with extended working time, allows easy installation for deep embedment up to 2.5 m. (see Figure 4-1, Figure 4-2, Figure 4-3)

HIT-FP 700 R Installation

Figure 4-1: Electric dispenser

Figure 4-2: Setting of rebar with HIT-FP 700 R

Figure 4-3: Freshly set rebar with HIT-FP 700 R

4.1 Differences and similarities between HIT-FP 700 R, grouts and resin-based mortar

HIT-FP 700 R as an inorganic cement-based mortar provides unique fire resistance properties which are superior to those of resin-based mortars. Due to its inorganic characteristics, HIT-FP 700 R has a more stable displacement and performance at high temperatures. However, unlike inorganic grouts, it is characterized by its safer, more flexible and increased user-friendly application properties, which resemble the application of resin-based mortars. HIT-FP 700 R is applied by using our standard two-component injection system. This technology tackles limitations for the installation direction [7], which is typical of grouts (i.e., only downwards or inclined). The automatic use of predefined mixing proportions during injection clearly reduces the risk of erroneous or inconsistent mixing proportions, which is vital for the performance and durability of the mortar [7] and may occur when handling commercially available grouts on the job site. A tailored smooth consistency helps to avoid the need for large drilling diameters when compared to the rebar size, minimizing the amount of HIT-FP 700 R mortar needed.

The qualified anchoring mortar for post-installed rebars typically follow these guidelines:

- Declaration of performance based on EN 1504-6 [8]
- ETA (European Technical Assessment) based on EAD 330087-02 [1]
- ESR (Evaluation Service Report) based on ICC-ES AC308 [9]

The EN 1504-6 [8] does not provide a qualification as detailed as the other two methods. The EN1504-6 is outdated and does not consider important parameters in the qualification process of mortars, which could yield to connections designed in an unconservative way [7]. Post installed rebars having an ETA or ESR approval and designed in accord to ACI 318 [10] or Eurocode 2 (EN 1992-1-1) [2] ensure the same safety level as for cast in rebar design. Hence the Declaration of performance based on EN1504-6 [8] does not provide an adequate safety level for the qualification of post-installed rebar connections and it is not compatible with design methods given by existing building codes [11].

HIT-FP 700 R Installation vs grouts

Figure 4-4: Installation of HIT-FP 700 R and generic grouts.

Furthermore, as with other Hilti injectable mortar portfolio, HIT-FP 700 R is offered with Hilti SafeSet technology, in which 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 dispenser before the element is inserted into the borehole. Hilti SafeSet system is a combination of anchor system components that significantly increase the rebar's robustness and help to significantly reduce potential user errors during the installation process.

Figure 4-5: SafeSet technology installation

4.2 Detailed installation characteristics of HIT-FP 700 R

Similar to many cementitious products, HIT-FP 700 R has a significantly longer curing time (days) related to the installation temperature when compared to “standard” injection systems (minutes) and small cracks and voids may be seen in HIT-FP 700 R material expelled from the top of the borehole. This is due to shrinkage. The presence of small cracks and voids are not critical and they are considered in the final assessment of ETA.

In order to support the workflow and reduce the waiting time, two additional times such as $t_{assemby}$ and $t_{pre\text{-}loading}$, between the setting and the full curing times, have been added to the IFU (Table 1). This allows a partial loading before the full design load can be applied.

Note | HIT-FP 700 R behaves differently than resin-based mortars and it is necessary to remove the used foil from the cassette once the installation is complete. Otherwise, the mortar will cure in the foil bag, and it will be extremely difficult to remove the foil bag from the cassette.

Table 1: IFU table for HIT-FP 700 R – curing at different temperatures.

		Rebar			
ø [°C]	ø [°F]	t_{work}	$t_{assembly}$	$t_{pre\text{-}loading}$ 75%	t_{cure} 100%
≥ 5 … 10	≥ 41 … 50	50 min	36 h	14 days	50 days
> 10 … 15	> 50 … 59	40 min	30 h	7 days	28 days
> 15 … 20	> 59 … 68	35 min	24 h	6 days	18 days
> 20 … 30	> 68 … 85	20 min	12 h	5 days	10 days
> 30 … 40	> 85 … 104	15 min	6 h	3 days	7 days
40	104	12 min	3 h	2 days	4 days

HIT-FP 700 R curing time concept

- t_{work}: describes the working time, or the period in which the mortar has not yet solidified and in which the user can insert the rebar. The working time ranges from a maximum of 50 minutes at 5°C to a minimum of 12 minutes at 40°C. The long working time allows an easy setting for deep embedment. Once the rebar is inserted it must not be moved.

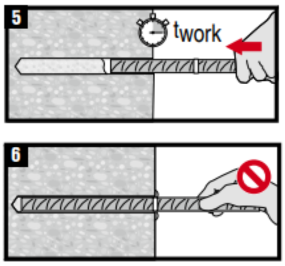


Figure 4-6: workflow of t_{work} as per IFU

- $t_{assembly}$: when t_{work} has passed, $t_{assembly}$ indicates the minimum waiting time before tying new rebars to the installed/set ones or pouring new concrete is allowed.

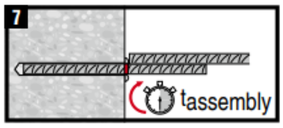


Figure 4-7: workflow of $t_{assembly}$ as per IFU

- $t_{pre\text{-}loading}$: It is the minimum waiting time needed before 75% of the final load can be applied to the set rebar. The $t_{pre\text{-}loading}$ is provided as additional guidance. However, the Engineer of Record must use their engineering judgment to decide whether or not pre-loading can be done prior to reaching the full curing time.

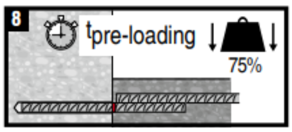


Figure 4-8: workflow of $t_{pre\text{-}loanding}$ as per IFU

- t_{cure}: the full curing time has passed and the full design load can be applied to the rebar.

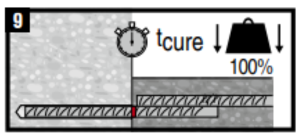


Figure 4-9: workflow of t_{cure} as per IFU

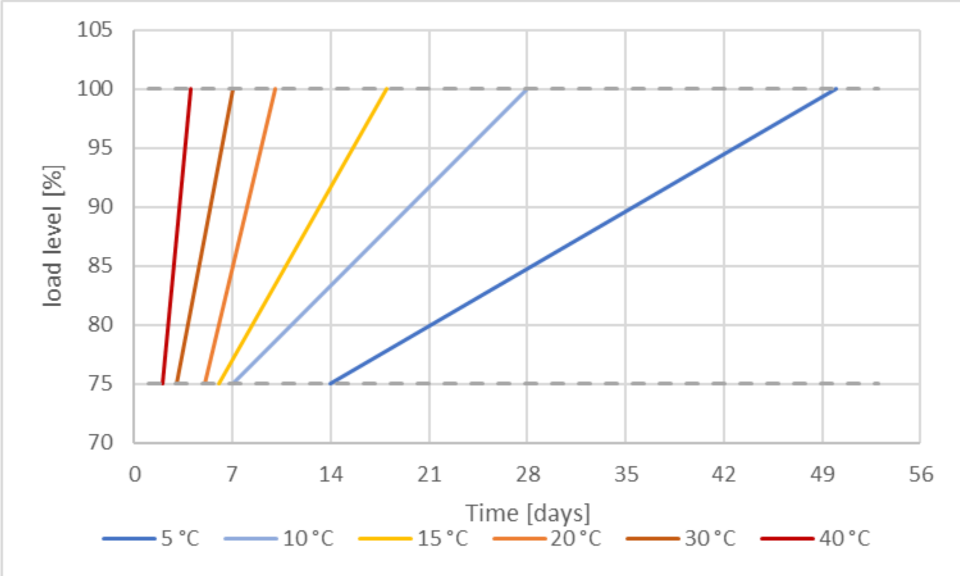


Figure 4-10: load level in function of the time at different temperatures.

4.3 EAD amendment: new state-of-the-art for the qualification of cement-based mortars

The qualification of post-installed rebar connections is regulated by the European Assessment Document EAD 330087 [12]. This document, in its previous versions, formally covered both resin-based and cementitious mortars in its scope. However, the qualification procedure given in the EAD has been used almost uniquely for resin-based products, systems that function by means of organic binders. As a consequence, chemical sensitivities of organic systems were mainly considered in the development of the testing protocols and assessment criteria of the EAD.

With the new Hilti technology allowing fully cementitious mortars to be used in post-installed rebar connections for frequent use, several aspects of performance related to cement-based products were investigated. The results of the research and review study led to a confirmation of the majority of the pre-existing requirements for both mortar types. In addition, some new requirements were introduced in order to account for the specific characteristics of inorganic binders in terms of microstructure stability, especially with regards to the porosity degree and long-term effects, as well as a tendency to a shrinking behavior.

These new qualification requirements are consolidated in the latest version of the document, namely EAD 330087-02 [1]. As a first step, the new document establishes a method to separate the mortar types into resin-based and cement-based mortars. This distinction was not clearly described in the previous versions, despite the presence of a few requirements dedicated to cementitious products. The method consists of a compositional analysis based on the mass loss over temperature for the assessed product.

Furthermore, two new test protocols apply specifically to the products classified as cement-based mortars. The first aspect to be assessed is the sensitivity of the rebar system for installations in low-relative humidity concrete. This test aims at verifying the influence on the bond strength of conditions related to dry outdoor and indoor climates and to a maximization of shrinkage effects. The potential water suction of the surrounding concrete may affect the cement hydration by altering the water-cement ratio of the mortar.

The second aspect to be assessed is the long-term stability of the mortar microstructure. This characteristic of performance is verified in an accelerated setup with severe exposure to high temperature and humidity, namely the so-called weathering conditions. This check is required to evaluate the sensitivity of the cementitious product to porosity variations, phase conversions and disjoining pressure related to the phenomena previously mentioned. The new requirements ensure that the published characteristic of performance in the ETA, especially the bond strength values, maintain the same reliability of the output of assessment required for resin-based mortars. This new qualification procedure, including specific criteria for cement-based mortars, now represents the state-of-the-art for the subject.

5. HILTI PROFIS ENGINEERING: AN EASY WAY TO SELECT THE RIGHT PRODUCT FOR FIRE DESIGN

Hilti PROFIS Engineering software gives engineers a quick and safer solution for designing post-installed rebars under fire conditions. The program determines splice and end anchorage lengths under hot conditions for accidental load combinations.

Furthermore, Hilti Software PROFIS Engineering design offers the following advantages:

- Flexibility to model fire conditions:
    - determine the temperature along the rebars by inputting the required fire duration exposure
    - enter a constant temperature along the rebars, calculated by engineers outside of PROFIS Engineering
- Calculate drill lengths for post-installed rebar in fire conditions
- Generate a clear and comprehensible design report containing information on the fire design results for your project documentation.

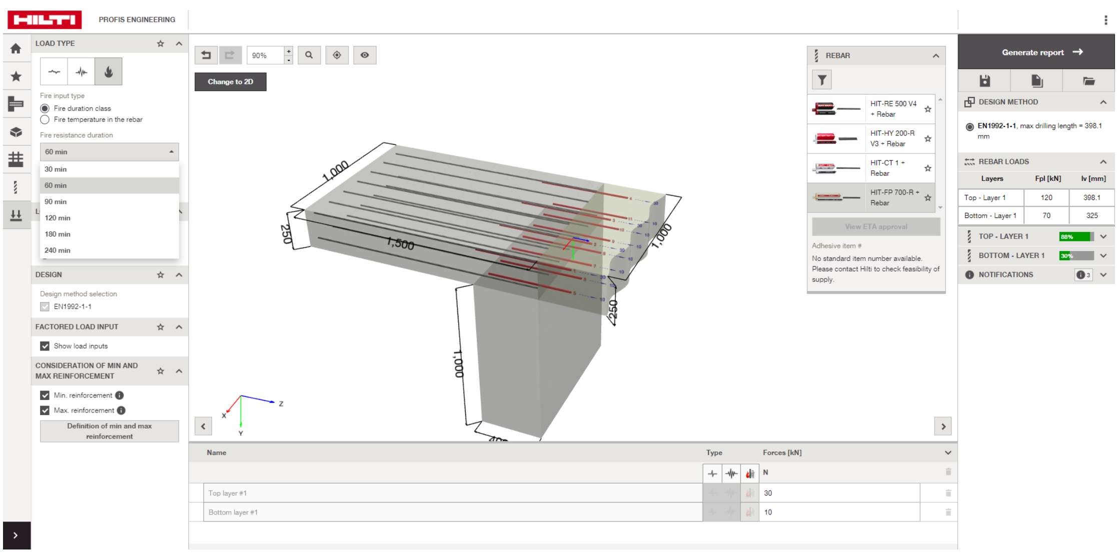
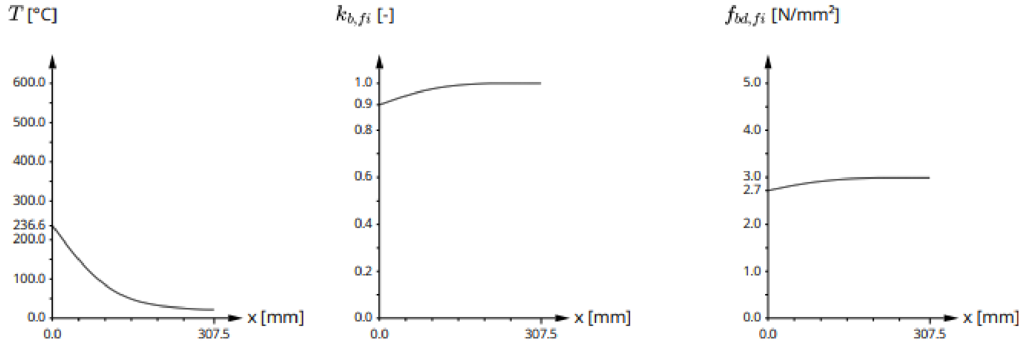


Figure 5-1: PROFIS Engineering, Post-installed rebar design



Rebar temperature distribution | Bond strength reduction factor distribution | Bond strength distribution

Figure 5-2: Temperature, bond strength reduction and bond strength distribution along anchorage length

Company:		Page:	1
Address:		Specifier:	
Phone | Fax:		E-Mail:	
Design:		Date:	
Rebar application:			

Specifier's comments:

1. Input data

General

Design method	EN 1992-1-1:2004 + AC:2010, EN 1992-1-2:2004 + AC:2008
Consider the effect of ΔF_{td}	yes
Verification of interface shear	no
Consider compression reinforcement for CSD	no
Application type	Slab extension, at support
Loading type	Fire
Fire resistance duration	60 min
Design working life	50 years

Product

Mortar	**HIT-FP 700-R**
Item number	not available (adhesive)
European Technical Assessment	Hilti Technical Data
Issued	-
Installation	Hammer drilling (HD), Installation Condition: Dry Concrete
Drilling direction	Drilling aid is used (this improves the angle of drilling)

Figure 5-3: Design report (extract)

6. REFERENCES

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