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Institut für Baustoffe, Massivbau und Brandschutz
Materialprüfanstalt für das Bauwesen

Expert Opinion

Document number: (3215/229/12) - CM of 04 October 2012

Client: Hilti Aktiengesellschaft
Buisness Unit Anchors
Feldkircherstraße 100

9494 Schaan
Fürstentum Liechtenstein

Order date: 27/07/2012

Order Ref. No.: Ref. 74378301/1

Order received: 27/07/2012

Subject: Expert Assessment of torque controlled expansion anchor HILTI stud anchor HSA, HSA-BW, HSA-R2 and HSA-R (dimensions M6 to M20) placed in non-cracked reinforced concrete (strength class ≥ C20/25 ≤ C50/60), for their reaction to fire to determine their fire resistance time when exposed to a standard temperature-time curve (ETK) in accordance with EN 1363-1 : 2012-10.

Valid until: 04 October 2017

This Expert Opinion consists of 9 pages (incl. cover sheet) and 3 annexes.

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1 Background and commission

With their order of 27/07/2012, Hilti Aktiengesellschaft commissioned MPA Braunschweig to prepare a fire-engineering design concept for the placed non-cracked reinforced concrete (strength class ≥ C20/25 ≤ C50/60). The evaluation covers torque controlled expansion anchor HILTI stud anchor HSA exposed to fire on one side only. If the fire attack is from more than one side, the values may be taken only, if the edge distance of the anchor is c ≥ 300 mm and ≥ 2 $h_{ef.}$

The fire-engineering design concept for the HILTI stud anchor HSA in connection with non-cracked reinforced concrete (strength class ≥ C20/25 ≤ C50/60) members exposed to the "Standard Temperature/Time Curve" (STC) according to the conditions given in EN 1363-1 [1] is based on tests made to examine mechanical anchors:

Also used as a basis were:

[1] EN 1363-1 : 2012-10, Fire resistance tests, Part 1: General requirements,

[2] CEN/TS 1992-4-1 : 2009-5, Design of fastenings for use in concrete Part 4-1: General,

[3] CEN/TS 1992-4-4 : 2009-5, Design of fastenings for use in concrete Part 4-4: Post-installed fasteners – Mechanical systems,

[4] European Technical Report TR 020: 2004-05, Evaluation of Anchorage in Concrete concerning Resistance to Fire,

[5] ETAG 001 Annex C, Guideline for European technical approval of metal anchors for use in concrete,

[6] ETA-11/0374 HILTI stud anchor HSA, issued 19 of July 2012,

[7] Data sheets provided by the client for the torque controlled expansion anchor HILTI stud anchor HSA,

[8] Evaluation report fire for the torque controlled expansion anchor HILTI stud anchor HSA, MPA Braunschweig, not published and

[9] EN 1992- 1-1, „EC 2“ : Design of concrete structures - Part 1-1: General rules and rules for buildings.

2 Description of construction product

2.1 Description of construction product (HILTI stud anchor HSA)

The HILTI stud anchor HSA (see also Figure 1) is a torque- controlled expansion anchor, based on [5], part 2, in the sizes M6, M8, M10, M12, M16 and M20, primarily exposed to static loads in normal-weight concrete. The HILTI stud anchor HSA is to be used subject to the above-named approval issued for cold-design for anchorages to static loadings in non-cracked reinforced and unreinforced normal weight concrete (strength class ≥ C20/25 and ≤ C50/60).

The HILTI stud anchor HSA consists of an anchor rod with an external thread including washer and nut on one end and a cone with an attached expansion sleeve on the other end. The anchor rod is made of carbon steel or stainless steel grade A2 or A4. The product made of stainless steel grade A2 is provided, but only used in structures subject to dry internal conditions, the characteristic material properties are equivalent. The different material codes are shown in Annex 3 of the ETA [6].

The HILTI stud anchor HSA has to be installed as described in the instruction for use of Hilti Aktiengesellschaft, using the tools specified in these data sheets. The anchor is placed into a drill hole, prepared with standard hammer drilling (HD) or diamond drilling (DD).

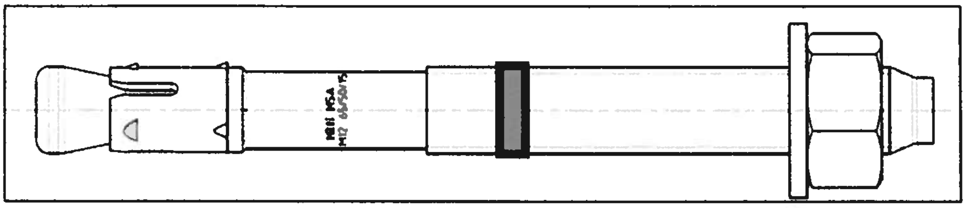

Figure 1: HILTI stud anchor HSA

For each anchor size there are 3 setting positions possible. The multiple embedments are marked as follows:

Setting position 1 (shallowest embedment depth):
$h_{nom,1}$ - beginning of the external thread of the bolt

Setting position 2 (medium embedment depth):
$h_{nom,2}$ - blue ring on external thread

Setting position 3 (deepest embedment depth):
$h_{nom,3}$ - no marking, given by the maximum of $t_{fix,3}$ (see Annex 3 of the ETA [6])

The installation and load application of the HILTI stud anchor HSA is regulated by the European Technical Approval (ETA [6]) and the instruction for use provided by Hilti Aktiengesellschaft.

3 Evaluation of the fire resistance for the HILTI stud anchor HSA

3.1 General

This evaluation concerns the torque controlled expansion anchor HILTI stud anchor HSA placed in non-cracked reinforced concrete (strength class ≥ C20/25 ≤ C50/60) used for normal structures under fire exposure. The fire conditions for the "Standard Temperature/Time Curve" (STC) are given in EN 1363-1 [1]. The fire resistance time is evaluated for the fire resistance periods of 30, 60, 90 and 120 minutes according to the design method for given in this CEN/TS [2] or TR020 [4].

In general, the duration of the fire resistance of anchorages depends mainly on the configuration of the structure itself (base materials, anchorage including the fixture). It is not possible to classify an anchor for its fire resistance. This evaluation concept includes the behavior of the anchorage in concrete and the parts outside the concrete. The influence of the fixation is considered unfavorable. The base material (reinforced concrete), in which the anchor shall be anchored, shall have at least the same duration of fire resistance as the anchorage itself.

The design of the anchorage under fire exposure has to be carried out as follows:

$S_{d,fi} \leq R_{d,fi(t)}$

$S_{d,fi} = \gamma_{F,fi} \times S_{k,fi}$

$R_{d,fi(t)} = R_{k,fi(t)} / \gamma_{M,fi}$

$S_{d,fi}$ = design value of action under fire exposure
$S_{k,fi}$ = characteristic value of action under fire exposure
$\gamma_{F,fi}$ = partial safety factor for action under fire exposure
$R_{d,fi(t)}$ = design value of resistance under fire exposure
$R_{k,fi(t)}$ = characteristic resistance under fire exposure
$\gamma_{M,fi}$ = partial safety factor for resistance under fire exposure

For the partial safety factors $\gamma_{F,fi}$ = 1,0 and $\gamma_{M,fi}$ = 1,0 is recommended in absence of other national regulations.

The determination is valid for unprotected anchors. For the anchor design, for all load directions and failure modes the limit values must be observed (characteristic resistance in ultimate limit state under fire exposure $R_{k,fi(t)}$.

The anchorages shall be designed under the responsibility of an engineer experienced in anchorages and concrete work either in accordance with [2] or [5]. The design methods must not be mixed.

3.1.1 Design of the non-cracked Concrete

Under service condition, including fire, the anchor with its entire anchorage depth shall be located **in non-cracked concrete**. Non-cracked concrete can be assumed for anchorages subjected to a resultant load F_{Sk} < 60 kN if the following condition is fulfilled.

$\sigma_L + \sigma_R < 0$ according to ETAG 001, Annex C [5] or CEN/TS 1992-4-1 [2]

σ_L = stresses in the concrete induced by external loads, including anchors loads.
σ_R = stresses in the concrete due to restraint of intrinsic imposed deformations (e.g. shrinkage of concrete) or extrinsic imposed deformations (e.g. due to displacement of support or temperature variations).

For a cold design, $\sigma_R = 3$ N/mm^2 should be assumed, if no detailed analysis is conducted.

For a hot design, a detailed analysis is required in any case. The stresses in the concrete due to restraint of intrinsic imposed deformations due to high temperatures caused by fire, needs to be evaluated.

The stresses σ_L and σ_R are calculated assuming that the concrete is non-cracked (state I). For plane concrete members that transmit loads in two directions (e.g. slabs, walls) the requirement shall be fulfilled for both directions.

3.1.2 Spalling

Local spalling is possible at fire attack. To avoid any influence of the spalling on the anchorage, the concrete member must be designed according to EN 1992-1-2 [9]. The members shall be made of concrete with quartzite additives and have to be protected from direct moisture; the moisture content of the concrete has to be like in dry internal conditions respectively.

The anchorage depth has to be increased for wet concrete by at least 30 mm compared to the given value in the approval.

3.2 Evaluation of the fire resistance for the HILTI stud anchor HSA (tension load)

3.2.1 Characteristic resistance for steel failure under fire exposure (tension load)

The characteristic resistance for the HILTI stud anchor HSA under tension loading for steel failure is based on the characteristic strength values $\sigma_{Rk,s,fi}$.

The characteristic resistance of an anchorage in case of steel failure ($N_{Rk,s,fi}$) under fire exposure is given in Annex 2. These values are also valid for the unprotected steel parts of the anchor outside the concrete.

3.2.2 Pull out failure under fire exposure (tension load)

The characteristic resistance for the HILTI stud anchor HSA under tension loading for pull-out failure ($N_{Rk,p,fi}$) is based on [2] and [4]. The characteristic resistance of an anchorage in case of pull-out failure under fire exposure is given in Annex 2.

According to ETA [6], the pull out resistance for HSA, HSA-BW, HSA-R2 and HSA-R is equal. For the sizes M8 to M16, setting position 1 and 2, M20 setting position 1, 2 and 3 pull out failure is not decisive. Nevertheless pull out failure may become decisive under fire exposure; therefore the pull out performance for these sizes and setting positions is derived from the characteristic concrete cone values.

3.2.3 Concrete cone failure under fire exposure (tension load)

The characteristic resistance for the HILTI stud anchor HSA under tension loading for concrete cone failure is based on [2] and [4].

The characteristic resistance of an anchorage in case of concrete cone failure ($N_{Rk,c\ fi}$) under fire exposure is given in Annex 2.

Further parameter like geometry, eccentricity and other boundary conditions must be considered separately if applicable.

3.2.4 Characteristic resistance for splitting failure under fire exposure (tension load)

The characteristic resistance for the HILTI stud anchor HSA under tension loading for concrete splitting failure is based on [8].

The characteristic resistance of an anchorage in case of concrete splitting failure ($N_{Rk,sp,fi}$) under fire exposure is given in Annex 2.

Further parameter like geometry, eccentricity and other boundary conditions must be considered separately if applicable.

3.3 Evaluation of the fire resistance for the HILTI stud anchor HSA (shear load)

The characteristic resistance for the HILTI stud anchor HSA under shear loading for steel failure is based on the characteristic strength values $\sigma_{Rk,s,fi}$.

The characteristic resistance of an anchorage in case of steel failure ($V_{Rk,s,fi}$) under fire exposure is given in Annex 3. These values are also valid for the unprotected steel parts of the anchor outside the concrete.

3.3.1 Characteristic resistance for pry-out failure under fire exposure (shear load)

The characteristic resistance for the HILTI stud anchor HSA under shear loading for concrete pry-out failure is based on [2] and [4].

The characteristic resistance of an anchorage in case of concrete pry-out failure ($V_{Rk,cp,fi}$) under fire exposure is given in Annex 3.

Further parameter like geometry, eccentricity and other boundary conditions must be considered separately if applicable.

3.3.2 Characteristic resistance for concrete edge failure under fire exposure (shear load)

The characteristic resistance for the HILTI stud anchor HSA under shear loading for concrete edge failure is based on [2] and [4].

The characteristic resistance of an anchorage in case of concrete edge failure ($V_{Rk,c,fi}$) under fire exposure is given in Annex 3.

Further parameter like geometry, eccentricity and other boundary conditions must be considered separately if applicable.

4 Notes

4.1 The assessment only relates the torque controlled expansion anchor HILTI stud anchor HSA, HSA-BW, HSA-R2 and HSA-R (dimensions M6 to M20) placed in non-cracked reinforced concrete (strength class ≥ C20/25 ≤ C50/60), due consideration being given to the conditions specified in the Hilti data sheets and ETA.

4.2 The assessment for the HILTI stud anchor HSA shall only apply in connection with RC members, whose fire-resistance rating must as a minimum correspond with the fire resistance period of the HILTI stud anchor HSA.

4.3 This expert report does not replace the required attestation (General Building Code Test Certificate – abP; type approval – abZ, ETA), but it may be used as a design proposal and thus as a basis for extension of (European) type approvals. A final assessment of the fire resistance rating will be made by the body issuing the certificate in the approval procedure.

4.4 The validity of this Expert Opinion will end on 04 October 2017.

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Dipl.-Ing. Maertins
Engineer in charge

Materialprüfanstalt f. d. Bauwesen MPA BS 3.1 Braunschweig

Braunschweig, dated 04 October 2012

List of annexes (3 annexes)

Table 1: Installation data, minimum thickness of concrete member, Minimum spacing and edge distance

Type	**HSA, HSA-BW, HSA-R2, HSA-R**																	
Anchor Size	**M6**			**M8**			**M10**			**M12**			**M16**			**M20**		
Setting position	①	②	③	①	②	③	①	②	③	①	②	③	①	②	③	①	②	③
Nominal anchorage depth h_{nom} [mm]	37	47	67	39	49	79	50	60	90	64	79	114	77	92	132	90	115	130
Diameter of clearance hole in the fixture d_f [mm]	7			9			12			14			18			22		
Width across flats S_W [mm]	10			13			17			19			24			30		
Depth of drill hole h_1 [mm]	42	52	72	44	54	84	55	65	95	72	87	122	85	100	140	98	123	138
Min. thickness of concrete member h_{min} [mm]	100	100	120	100	100	120	100	120	160	100	140	180	140	160	180	160	220	220
Hammer drilling (HD) 																		
Nominal diameter of drill bit d_0 [mm]	6			8			10			12			16			20		
Cutting diameter of drill bit d_{cut} [mm]	6,40			8,45			10,45			12,5			16,5			20,55		
Diamond drilling (DD) 																		
Diamond coring system	-			-			-			DD 30-W			DD 30-W			DD 30-W		
Core bit	-			-			-			DD-C 12 TS DD-C 12 TL			DD-C 16 TS DD-C 16 TL			DD-C 20 TS DD-C 20 TL		
Standard installation torque and the required minimum edge and space distance																		
Standard installation torque T_{inst} [Nm]	5			15[1)]			25[1)]			50[1)]			80[1)]			200		
Minimum spacing s_{min} [mm]	35	35	35	35	35	35	50	50	50	70	70	70	90	90	90	195	175	175
Fire attack from one side																		
Minimum edge c_{min} [mm]	60	80	120	60	80	140	80	100	160	100	130	200	130	160	240	150	200	230
Fire attack from more than one side																		
Minimum edge c_{min} [mm]	≥ 300																	

1) Alternatively, the anchor can be tightened with an impact screw driver in combination with a special socket with the required setting time [6].

Table 2: Characteristic resistance for the HILTI stud anchor HSA under tension loading in dependence of the fire resistance time

Type	HSA, HSA-BW, HSA-R2, HSA-R																	
Anchor Size	**M6**			**M8**			**M10**			**M12**			**M16**			**M20**		
Setting position	①	②	③	①	②	③	①	②	③	①	②	③	①	②	③	①	②	③
Nominal anchorage depth h_{nom} [mm]	37	47	67	39	49	79	50	60	90	64	79	114	77	92	132	90	115	130
Steel failure tension																		
Characteristic resistance tension in dependence of the fire resistance time 30 [min] $N_{Rk,s,fi}$ [kN]	0,20			0,37			0,87			1,69			3,14			4,90		
60 [min] $N_{Rk,s,fi}$ [kN]	0,18			0,33			0,75			1,26			2,36			3,68		
90 [min] $N_{Rk,s,fi}$ [kN]	0,14			0,26			0,58			1,10			2,04			3,19		
120 [min] $N_{Rk,s,fi}$ [kN]	0,10			0,18			0,46			0,84			1,57			2,45		
Pull out failure																		
Characteristic resistance in concrete ≥ C20/25 in dependence of the fire resistance time 30 [min] 60 [min] 90 [min] $N_{Rk,p,fi}$ [kN]	1,1	1,4	1,7	1,6	2,4	3,0	2,4	3,3	4,7	3,3	5,0	6,6	5,0	6,8	9,4	6,2	9,5	11,7
120 [min] $N_{Rk,p,fi}$ [kN]	0,9	1,1	1,4	1,2	1,9	2,4	1,9	2,7	3,8	2,7	4,0	5,3	4,0	5,4	7,5	4,9	7,6	9,3
Concrete cone failure[1]																		
Characteristic resistance in concrete ≥ C20/25 in dependence of the fire resistance time 30 [min] 60 [min] 90 [min] $N_{Rk,c,fi}$ [kN]	0,9	1,8	5,0	0,9	1,8	7,4	1,8	3,2	10,3	3,2	6,1	18,0	6,1	10,3	28,4	8,8	18,0	25,5
120 [min] $N_{Rk,c,fi}$ [kN]	0,7	1,5	4,0	0,7	1,5	5,9	1,5	2,5	8,2	2,5	4,9	14,4	4,9	8,2	22,7	7,0	14,4	20,4
Spacing $s_{cr,N}$ [mm]	120	160	240	120	160	280	160	200	320	200	260	400	260	320	480	300	400	460
Edge distance $c_{cr,N}$ [mm]	60	80	120	60	80	140	80	100	160	100	130	200	130	160	240	150	200	230
Concrete splitting failure[2]																		
Characteristic resistance in concrete ≥ C20/25 in dependence of the fire resistance time 30 [min] 60 [min] 90 [min] $N_{Rk,sp,fi}$ [kN]	1,1	1,4	1,7	0,9	1,8	3,0	1,8	3,2	4,7	3,2	6,1	6,6	6,1	10,3	9,4	8,8	18,0	25,5
120 [min] $N_{Rk,sp,fi}$ [kN]	0,9	1,1	1,4	0,7	1,5	2,4	1,5	2,5	3,8	2,5	4,9	5,3	4,9	8,2	7,5	7,0	14,4	20,4
Spacing $s_{cr,sp}$ [mm]	133	160	173	173	240	267	253	280	387	267	333	413	307	373	507	347	493	533
Edge distance $c_{cr,sp}$ [mm]	67	80	87	87	120	133	127	140	193	133	167	207	153	187	253	173	247	267
Partial safety factor $\gamma_{M,fi}$[3] [-]	1,0																	

1) For design of splitting failure according CEN/TS 1992-4-4, 6.2.1.4 and for design according ETA 001, Annex C 5.2.2.4; replace $N^0_{Rk,c}$ by $N_{RK,c,fi}$.

2) For design of splitting failure according CEN/TS 1992-4-4, 6.2.1.5 and for design according ETA 001, Annex C 5.2.2.6; replace $N^0_{Rk,c}$ by $N_{RK,sp,fi}$.

3) In absence of other national regulations.

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Table 3: Characteristic resistance for the HILTI stud anchor HSA under shear loading in dependence of the fire resistance time

Type	HSA, HSA-BW, HSA-R2, HSA-R																	
Anchor Size	M6			M8			M10			M12			M16			M20		
Setting position	①	②	③	①	②	③	①	②	③	①	②	③	①	②	③	①	②	③
Nominal anchorage depth h_{nom} [mm]	37	47	67	39	49	79	50	60	90	64	79	114	77	92	132	90	115	130
Steel failure tension without lever arm																		
Characteristic resistance shear in dependence of the fire resistance time 30 [min] $V_{Rk,s,fi}$ [kN]	0,20			0,37			0,87			1,69			3,14			4,90		
60 [min] $V_{Rk,s,fi}$ [kN]	0,18			0,33			0,75			1,26			2,36			3,68		
90 [min] $V_{Rk,s,fi}$ [kN]	0,14			0,26			0,58			1,10			2,04			3,19		
120 [min] $V_{Rk,s,fi}$ [kN]	0,10			0,18			0,46			0,84			1,57			2,45		
Steel failure tension with lever arm																		
Characteristic resistance shear in dependence of the fire resistance time 30 [min] $M^0_{Rk,s,fi}$ [Nm]	0,2			0,4			1,1			2,6			6,7			13,0		
60 [min] $M^0_{Rk,s,fi}$ [Nm]	0,1			0,3			1,0			2,0			5,0			9,7		
90 [min] $M^0_{Rk,s,fi}$ [Nm]	0,1			0,3			0,7			1,7			4,3			8,4		
120 [min] $M^0_{Rk,s,fi}$ [Nm]	0,1			0,2			0,6			1,3			3,3			6,5		
Concrete pry-out failure[1)]																		
k-Factor[2)] k [-]	1	1	2	1	1,5	2	2,4	2,4	2,4	2	2	2	2,9	2,9	2,9	2	3,5	3,5
Characteristic resistance shear in concrete ≥ C20/25 in dependence of the fire resistance time 30 [min] 60 [min] 90 [min] $V_{Rk,cp,fi}$ [kN]	1,1	1,4	1,7	0,9	1,8	3,0	1,8	3,2	4,7	3,2	6,1	6,6	6,1	10,3	9,4	8,8	18,0	25,5
120 [min] $V_{Rk,cp,fi}$ [kN]	0,9	1,1	1,4	0,7	1,5	2,4	1,5	2,5	3,8	2,5	4,9	5,3	4,9	8,2	7,5	7,0	14,4	20,4
Concrete edge failure[3)]																		
Characteristic resistance shear in concrete ≥ C20/25 in dependence of the fire resistance time 30 [min] 60 [min] 90 [min] $V^0_{Rk,c,fi}$ [kN]	$0,25 \times V^0_{Rk,c}$ [2)]																	
120 [min] $V^0_{Rk,c,fi}$ [kN]	$0,20 \times V^0_{Rk,c}$ [2)]																	
Partial safety factor $\gamma_{M,fi}$ [4)] [-]	1,0																	

1) For design according CEN/TS 1992-4-4, 6.2.2.3 and for design according ETA 001, Annex C 5.2.3.3; replace $N^0_{Rk,c}$ by $V^0_{Rk,c}$.

2) k_3 according to CEN/TS 1992-4-4, 6.2.2.3

3) For design according CEN/TS 1992-4-4, 6.2.2.4.2 and for design according ETA 001, Annex C 5.2.3.4; replace $V^0_{Rk,c}$ by $V^0_{Rk,c,fi}$.

4) In absence of other national regulations.