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c/o Institut für Werkstoffe im Bauwesen
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Independent

Technical Assessment

on the durability of fischer UltraCut FBS II CP

Product name:
fischer UltraCut FBS II CP Ø8 to Ø14

Product type:
Screw anchor

Manufacturer:
fischerwerke GmbH & Co. KG

Validity:
5 years

Assessment based on the documents:
ETA-15/0352, EAD 330232-02-0601, EN ISO 9227, NT MAT 003:2002-05, EN ISO 6270-2 and DIN 50969

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Number of pages: 12 Gez. Prof. Dr.-Ing. Jan Hofmann

1. Introduction and procedure

The fischer UltraCut FBS II CP screw anchor has an European technical assessment [1] for cracked and uncracked concrete. The application according to the ETA is limited to dry indoor conditions for the specially coated UltraCut FBS II CP version although the corrosion behaviour is better than for the galvanised version. According to the European technical assessment [1], a service life of 50 years is aimed for dry indoor conditions.

The company fischerwerke GmbH & Co. KG would like to use the fischer UltraCut FBS II CP screw anchor also under outdoor conditions up to corrosive class C3 medium with a reduced service life of maximum 25 years. Due to the corrosive conditions C3, in particular the existing changing humidity, a deterioration of the existing coating is to be expected. For this reason, the risk of hydrogen embrittlement and a resulting screw failure is assessed. Various tests were carried out for the assessment of the durability of the coating due to atmospheric corrosion and hydrogen embrittlement. The results are summarised and evaluated in the following sections.

2. Literature

[1] ETA-15/0352: European Technical Assessment, fischer Concrete screw UltraCut FBS II of 5 October 2020, DIBt Berlin."

[2] EN 206:2013, Concrete: definition, properties, manufacture and conformity; German version EN 206:2013 Concrete – Specification, performance, production and conformity, January 2017, Berlin 2017.

[3] FAST 21-012-3: Durability of fischer Concrete Screw FBS II CP, Fastening and Strengthening Solutions for Testing │Technology │Teaching @University Stuttgart.

[4] European Organisation for Technical Approvals: EAD330232-02-0601, Metal Anchors for Use in Concrete.

[5] EN 1992-4:2018, Eurocode 2, Design and construction of reinforced concrete and pre-stressed concrete structures. Part 4, German version DIN EN 1992-4, Berlin 2019.

[6] European Organisation for Technical Approvals: TR 045, Design of Metal Anchors For Use In Concrete Under Seismic Actions“.

[7] U. Nürnberger, Corrosion and corrosion protection in the building industry (Volume 1 and 2). Bauverlag GmbH, Wiesbaden and Berlin 1995.

[8] T. Müller, G. Ebell, and A. Burkert, "Risiko der Wasserstoffentwicklung an martensitischen Schraubankern unter baupraktischen Bedingungen: Untersuchungsbericht der Bundesanstalt für Materialforschung und -prüfung", Bautechnik, Bd. 97, Nr. 11, S. 749–755, Nov. 2020.

[9] D. Eberhardt, "Hydrogen Development and Zinc Deposition at Silver Single Crystal Electrodes", University of Ulm, 2001. doi: 10.18725/OPARU-65.

[10] EN ISO 12944:2018: Paints and varnishes - Corrosion protection of steel structures by protective paint systems.

[11] ISO 6270-2:2018: Paints and varnishes - Determination of resistance to humidity - Part 2: Condensation (in-cabinet exposure with heated water reservoir).

[12] Prüfzertifikat Auftragsnummer 20200238-A, Kondenswasser-Konstant-Klimatest gemäß DIN EN ISO 6270-2 CH:2018, IGOS GmbH & Co. KG.

[13] Prüfzertifikat Auftragsnummer 20200238-A, Salzsprühnebeltest gemäß DIN EN ISO 9227, NSS:2017, IGOS GmbH & Co. KG.

[14] Prüfzertifikat Auftragsnummer 20200237-A, Nordtest Methode gemäß NT MAT 003:2002-05, IGOS GmbH & Co. KG.

[15] EN ISO 9227:2017: Corrosion tests in artificial atmospheres - Salt spray tests.

[16] NT MAT 003, Assessment of corrosion protection classes for in-organic coating on steel, Published by Nordtest, SSN: 1457–0564, Approved 2002-05.

[17] DIN 50969-1:2009: Prevention of hydrogen-induced brittle fracture of high-strength steel building elements - Part 1: Advice on the prevention.

3. Description and installation of the product

The European Technical Assessment of the CP-Version covers cracked and uncracked concrete as well as seismic and fire loads up to fire resistance class R 120. The function and installation of the product as well as the most important geometric parameters and installation parameters are given in the ETA [1] and valid in conjunction with this independent technical assessment.

4. Durability performance

4.1 Environmental categories

The categories according to EN ISO 12944 [10] are described in the following. The performed corrosion and embrittlement tests are described briefly in the following section. The test shall qualify the fischer UltraCut FBS II CP screw anchor for the different corrosion classes according to EN ISO 12944 [10]. The classes can be described as following:

Category C1: This category is mainly aimed at assessments of heated buildings with clean atmospheres (Indoor conditions). Dry indoor environments are areas without condensation, e.g.

- office buildings, shops, schools or hotels schools or

Category C2: Category defined for assessing atmospheres with low pollution levels (Indoor conditions), or unheated buildings where condensation may occur, e.g.,

- warehouses, sports halls, etc.
- with temporary condensation e.g. storage sheds, bathroom, kitchen.
- areas with low pollution and and/or salt from sea water with a distance of minimum 10 km from the sea.

Category C3: This category is intended for assessing urban and industrial atmospheres (Outdoor conditions) with moderate sulphur dioxide pollution. Also, for manufacturing halls with high humidity and some air pollution, e.g.,

- food processing plant, laundries, brewery plants, dairy plants.
- Areas with moderate concentration of pollutants and/or salt from sea water with a distance of minimum 5 km from the sea

Category C4: Defined to assess industrial and coastal areas with moderate salinity such (Special conditions**)** as e.g.,

- areas with heavy industrial pollution close to chemical plants e.g. petrochemical, coal industry, swimming pools, ships and shipyards.
- coastal areas with a distance from the sea less than 1 m – 1,0 km

- areas close to roadways treated with de-icing salts with a distance from roadways smaller than 5 -10 m, …

Category C5, and Category CX are corrosiveness category applicable to very high extremely corrosive environments and are not explained in detail here, because the Fischer UltraCut FBS II CP cannot be used anytime for such corrosion conditions.

Furthermore, the categories C1 to C5 given above can be subdivided by the following classification:

- Low (L): 2 to 5 years
- Average (M): 5 to 15 years
- High (H): 15 to 25 years or more

The classification and qualification of the screw anchor fischer UltraCut FBS II CP for at least category C3 (H) means C3 for 25 years is shown in the following sections using results of different corrosion tests.

4.2 Condensation constant climate test (EN ISO 6270-2)

The following condensation constant climate tests were carried out on coated steel screws to classify them into the corrosion categories. The test was carried out in accordance with EN ISO 6270-2 [11] with a duration of 480 h. In the tests, only the corrosion behaviour of the head and shaft of the screws was evaluated.

Testing time	Evaluation / classification	
480 h	9x passed	C3 for 25 years C4 for 25 years C5 for 15 years

Table 1: Summary of the of the test results of the condensation constant climate test with a maximum duration of 480 h.

The results of the investigations show that the concrete screws meet the requirements. The following classifications C3 (25 years) according to EN ISO 12994-6 can be established. A corresponding test certificate from IGOS GmbH & Co. KG is available. Detailed results are contained in the associated test report [11].

4.3 Salt Spray Test (EN ISO 9227)

To classify the screws for different corrosion categories, salt spray tests according to EN ISO 9227 [15] were carried out with the FBS II CP screw anchors. The following tests were carried out for the classification according to EN ISO 12944 [10]. The results for a test duration up to 1440 h are summarised in the following table.

Testing time	Evaluation / possible classification	
[h]	**[-]**	**[-]**
768 h	9 x passed.	C3 more than 25 years C4 for 25 years C5 medium (medium)
1440 h	9 x passed	C4 more than 25 years C5 for 25 years

Table 2: Summary of the test results of the salt spray tests for a test duration up to 1440 h.

The following classifications C3 (25 years) according to EN ISO 12994-6 can be established. A corresponding test certificate of IGOS GmbH & Co. KG is available. Detailed results are contained in the associated test report [13].

4.4 North test (NT MAT 003)

To classify the concrete screws FBS II CP according to NT MAT 003 [16] also corrosion tests with changing conditions were carried out. In the tests, only the corrosion behaviour of the head and shaft of the screws was evaluated.

The results of the north test are summarised in the following table.

Cycle No.	Zinc		Steel	
	[µm]	**Class**	**[µm]**	**Class**
01	4,5	1,6	23,9	1,3
02	8,5	2,1	63,4	2,1
03	12,1	2,2	103,0	2,5
06	27,1	2,9	181,2	3,1
09	38,1	3,3	236,5	3,3
11	44,8	3,5	274,7	3,5
15	64,5	4,1	405,4	4,0

Table 3: Summary of the material removal rates observed in the North-Test.

A total of 15 test cycles were carried out. One cycle consisting of

- 1 day salt spray test (35 ± 2 °C),
- 4 days condensation alternating climate test (8 h constant condensation at 40 ± 3 °C followed by 16 h storage at 23 ± 2 °C and 75 ± 5 % relative humidity)
- 2 days drying (at 23 ± 2 °C and 50 ± 5 % relative humidity).

The total duration of the tests is 105 days. The results of the tests show that a corrosion class C4 is achieved. A corresponding test certificate of IGOS GmbH & Co. KG is available [14].

4.5 Embrittlement tests according to DIN 50969

The applied tensile load was increased while storing the screw in a 5% NaCl solution at a pH value of 12.5. The tests according to DIN 50969 [17] differ essentially from the tests according to EAD 330232 [4]. The duration of the test is only about 36 hours, whereby the load is stepwise increased until failure of the screw. The amount of measured hydrogen for the 36 hours and extrapolated to 30 days is equivalent to the hydrogen produced in the N3 test according to EAD 330232 [4].

4.6 Durability against hydrogen embrittlement (EAD 330232)

From the current literature [7] it can be deduced that high-strength or hardened steel types are susceptible to embrittlement in the presence of hydrogen. As a result, cracking can occur, which can lead to failure with a time delay. An increase in the amount of atomic hydrogen also leads to an increase in the amount of hydrogen absorbed in the steel, which increases the risk of hydrogen-induced embrittlement and spontaneous cracking [7], [8], [9].

The investigations carried out to clarify if a sufficiently strong cathodic polarisation of the screw anchor will occur. The measurements of the charge quantities show that the duration of hydrogen production is usually less than 70 days. Only in 5% of all investigated applications the time of hydrogen production exceeds 70 days.

4.6.1 Test duration for the maximum expected quantity of produced hydrogen

The amount of produced hydrogen in the tests according to EAD 330232 [4] and the tests according to DIN 50969 [17] is compared with the amount of produced hydrogen in the potentiostatic tests. In the N3 tests according to EAD 330232 [4] the concrete screw is exposed to an approximately 3.2 times higher amount of produced hydrogen than expected in a real application (potentiostatic tests). Basically, the comparison of the charge quantities shows that 30 days (720 h) of N3 test duration according to EAD 330232 [4] correspond to about 70 days under real conditions. For this reason, 720 h of hydrogen exposure in the N3 tests corresponds to the maximum exposure time observed in real applications.

4.6.2 Maximum service load to avoid hydrogen embrittlement failure

In the hydrogen embrittlement tests different test durations with different load levels were realised. The tests were carried out with a test duration between 100 h to 1500 h and different load levels. The reference tensile capacity in case of steel failure without hydrogen exposure was tested to 46.6 kN.

Depending on the load levels and the exposure time to hydrogen the number of failed screws can be evaluated. The results show that for an applied load of 17 kN the likelihood of a failure within 720 h of hydrogen exposure is very small. The applied load level of 17 kN corresponds to a utilisation of approx. 40 % with respect to the reference load of 46.6kN.

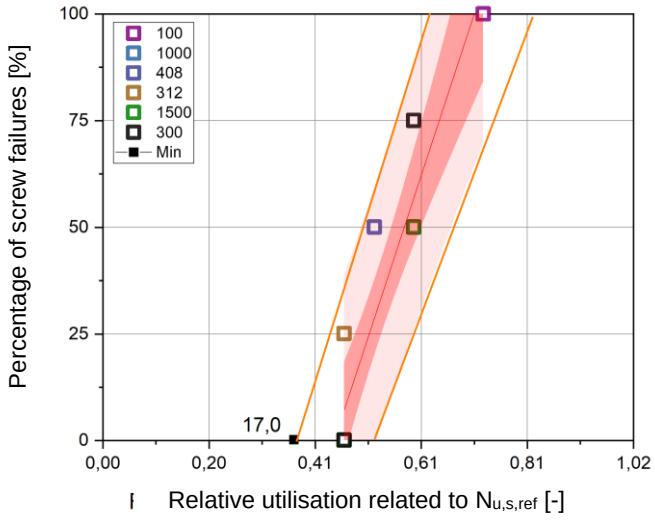


Figure 1: Relationship between test load and proportion of screw breaks for different test durations.

The prerequisite for using these results is that the corrosion conditions in the area of the screw and fixture are closely to the tested one or more favourable. In case of any doubts the manufacturer has to assess the existing conditions. To avoid hydrogen embrittlement for screws larger than Ø8, the steel capacity must be limited to 40% of the characteristic steel resistance.

$N_{Rk,s} \leq 0,4 \cdot N_{Rk,s,ETA} \leq 0,4 \cdot 1,0 \cdot A_s \cdot f_{uk,s}$
$V_{Rk,s} \leq 0,4 \cdot V_{Rk,s,ETA} \leq 0,4 \cdot 0,5 \cdot A_s \cdot f_{uk,s}$

5. Mechanical performance

5.1 Characteristic resistance under tension loading

The characteristic resistance of the fischer FBS II CP screw anchors is given in ETA-15/0352 [1]. The performance is valid for dry indoor conditions. For corrosion conditions C3 (25 years) the performance in case of steel failure shall be limited to 40% of the value $N_{Rk,s}$ given in the ETA-15/0352 [1]. The reduced values are summarised in the following table.

Size			**FBS II CP**										
			8		**10**			**12**			**14**		
Embedment depth	**h_{nom}**	**[mm]**	**50**	**65**	**55**	**65**	**85**	**60**	**75**	**100**	**65**	**85**	**115**
Steel failure for tension load													
Characteristic resistance	$N_{Rk,s}$	[kN]	14		22			30,4			41,2		
Partial factor	$\gamma_{Ms,N}$	[-]	1,4										

Table 4: Summary of the reduced tension steel capacity for corrosion category C3 medium.

5.2 Characteristic resistance under shear loading

The characteristic resistance of the fischer FBS II CP screw anchors is given in ETA-15/0352 [1]. The performance is valid for dry indoor conditions. For corrosion conditions C3 medium the performance in case of steel failure shall be limited to 40% of the value $V_{Rk,s}$ given in the ETA-15/0352 [1]. The reduced values are summarized in the following table.

Size			**FBS II CP**										
			8		**10**			**12**			**14**		
Embedment depth	**h_{nom}**	**[mm]**	**50**	**65**	**55**	**65**	**85**	**60**	**75**	**100**	**65**	**85**	**115**
Steel failure for shear load													
Characteristic resistance	$V^0_{Rk,s}$	[kN]	5,2	7,6	11,8		14,0	12,8		17,1	18,6		24,7
Partial factor	$\gamma_{Ms,V}$	[-]	1,5										
Factor for ductility	k_7		1,0										
Characteristic bending resistance	$M^0_{Rk,s}$	[Nm]	20,4		38			66			107,6		

Table 5: Summary of the reduced shear steel capacity for corrosion category C3 medium.

5.3 Displacements

The displacements of the fischer FBS II CP screw anchors is given in ETA-15/0352 [1] and is valid for corrosion class C1 to C3 for an exposure of 25 years.

5.4 Characteristic resistance under fire

The characteristic resistance of the fischer FBS II CP screw anchors in case of fire impact is given in ETA-15/0352 [1]. The performance is valid for dry indoor conditions. For corrosion conditions C3 (25 years) the performance in case of steel failure shall be limited to 40% of the value given in the ETA-15/0352 [1].

5.5 Characteristic resistance under seismic loading

The characteristic resistance of the fischer FBS II CP screw anchors in case of seismic loading (seismic performance categories C1 and C2) is given in ETA-15/0352 [1]. The performance is valid for dry indoor conditions. For corrosion conditions C3 (25 years) the performance in case of steel failure shall be limited to 40% of the value given in the ETA-15/0352 [1]. The reduced values are summarised in the following table.

Size			**FBS II CP**			
			8	**10**	**12**	**14**
Embedment depth	**h_{nom}**	**[mm]**	**65**	**85**	**100**	**115**
Steel failure for tension load and shear load						
Characteristic resistance	$N_{Rk,s,C1}$	[kN]	14,0	22	30,4	41,2
	$V_{Rk,s,C1}$		4,6	8,9	10,8	15,3
Without filling of the annular gap	α_{gap}	[-]	0,5			
With filling of the annular gap			1,0			

Table 6: Summary of the reduced tension and shear steel capacity for corrosion category C3 (25 years) for seismic performance category C1.

Size			**FBS II CP**			
			8	**10**	**12**	**14**
Embedment depth	**h_{nom}**	**[mm]**	**65**	**85**	**100**	**115**
Steel failure for tension load and shear load						
Characteristic resistance	$N_{Rk,s,C2}$	[kN]	14,0	22,0	30,4	41,2
	$V_{Rk,s,C2}$		5,3	8,2	12,0	14,1
With filling of the annular gap	α_{gap}	[-]	1,0			

Table 7: Summary of the reduced tension and shear steel capacity for corrosion category C3 (25 years) for seismic performance category C2.

6. Summary and notes

The evaluations of the potentiostatic tests show the maximum time of hydrogen production is about 70 days. The N3 hydrogen embrittlement tests show, that the produced amount of hydrogen is equivalent for a testing time of 720 h. Furthermore the likelihood of failure due to hydrogen embrittlement is about 5% if the utilisation, based on the steel load-bearing capacity, is less than 40%. The evaluation is based on specified corrosion conditions. The conditions that control the production of hydrogen at the surface of the concrete screw in an application therefore must correspond (or be more favourable) compared to the tested conditions.

The resistance of the screw coating to general corrosion attack was investigated and categorised using the salt spray test, the condensate constant climate test and the North Test. All the tests show, that the coating fulfils the requirements according to EN ISO 12944 [10] for corrosion class C3 medium up to a service life of 25 years.

The decision on the required corrosion protection must be made by the customer or a corrosion expert. The end of service life for the UltraCut FBS II CP screw anchors is reached, if red rust is visible over a large fraction of the product and structural deterioration can occur.

National or international codes, standards or regulations, customer and/or industry specific guidelines must be independently considered and evaluated. The evaluation of the durability is only related to the standards EAD 330232-02-0601, EN ISO 9227, NT MAT 003:2002, EN ISO 6270-2 and DIN 50969.
These guidelines apply to atmospheric corrosion only. **Special types of corrosion, such as crevice corrosion or hydrogen assisted cracking must be evaluated independently**.

Suitability for a specific application can be significantly affected by localised conditions. Such conditions are for example elevated temperatures and humidity, high levels of airborne pollutants, direct contact with corrosive products (e.g. chemically-treated wood, waste water, concrete additives, cleaning agents, acids, …), direct contact to young concrete, electrical current, contact with different metals, restrained areas (e.g.

crevices), physical damage of the coating or enrichment of pollutants on the product. The suitability of the UltraCut FBS II CP screw anchor for a specific application depends on specific corrosion conditions. These conditions should be in the tested range if the UltraCut FBS II CP screw anchors are used in an application with corrosion category C3 medium up to 25 years of service life.

Also combinations of different conditions may affect the corrosion behaviour and lead to an increased corrosion process compared to the tested conditions. In such a case, the application of the fischer UltraCut FBS II CP screw anchor shall be avoided.

To avoid contact corrosion, the fastener must be made of a more noble material or the same material than the fastened part. The UltraCut FBS II CP screw anchor is suitable for fastening parts like HDG steel, aluminium, or painted carbon steel.