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Evaluation of creep tests with Fischer adhesive FIS EM

Dear Mr. Grün,

sustained load tests were performed at the independent test lab Institut für Werkstoffe im Bauwesen, University Stuttgart, with the Fischer adhesive FIS EM at 20°C. In the following the sustained load tests are evaluated according to AC308.

1 Evaluation of the sustained load tests

The following evaluation is based on the regulations according to [G1].

$$N_{sust,sl} = 0{,}55 \cdot \overline{N_{o,i}} \left(\frac{f_{c,test}}{f_{c,test2}} \right)^{n} \qquad (1.1)$$

To show the suitability of the Fischer adhesive FIS EM under sustained loading creep tests were performed with size M10 at ϑ= 20°C (N_{sust}= 24,9 kN, n= 5 tests). The tests were performed with confined support in low strength uncracked concrete. According to [G1] each test shall have a minimum duration of 42 days (1008 hours). The constant tension load to be applied in the creep tests is calculated according to Equation (1.1). The reference value $\overline{N}_{o,i}$ is taken from unconfined reference tests in low strength concrete at the temperature at which the sustained load tests were performed.

During sustained loading the displacements of the anchors were recorded. Shortly after the sustained loading the anchors were unloaded and the residual capacity was determined in a confined tension test at the temperature of the creep tests.

According to [G1] the total displacement over the anchor intended service life which includes the initial elastic displacement plus creep displacement is determined for each specimen by projecting a logarithmic trend line forward over the intended anchor service life. The trend line shall be determined by calculating a least squares fit through the data points using the Findley approach (Equation (1.2)) and shall be constructed with data from not less than the last 20 days (minimum 20 data points) of the creep tests ([G1]). The estimated displacement corresponding to anchor intended service life is calculated for each test according to Equation (1.3).

$$\Delta(t) = \Delta_{t=0} + a \cdot t^b \qquad (1.2)$$

With $\Delta(t)$ = total displacement recorded in the test at the time t
$\Delta_{t=0}$ = initial displacement recorded under sustained load
t = time corresponding to the total recorded displacement
a, b = constants evaluated by regression analysis

$$\Delta_{service} = \Delta_{t=0} + a \cdot t_{service}^{\ b} \qquad (1.3)$$

With $\Delta_{service}$ = extrapolated estimate of the total displacement over the anchor intended service life
$\Delta_{t=0}$ = initial displacement recorded under sustained load
$t_{service}$ = anchor intended service life
= 50 years at standard temperature= 438.000 h
= 10 years at elevated temperature= 87.600 h
a, b = constants evaluated by regression analysis

The mean values of the extrapolated estimates of the total displacement over the anchor intended service life $\overline{\Delta}_{service}$ at standard temperature and at the long term elevated temperature shall not exceed Δ_{lim}, where Δ_{lim} is the mean displacement corresponding to loss of adhesion N_{adh} as measured in the corresponding reference test at standard temperature and at elevated temperature. The calculated estimated displacement $\Delta_{service}$ for any one test shall not exceed $1{,}2 \cdot \Delta_{lim}$. In the reference tests the average displacement at load at loss of adhesion was Δ_{lim}= 1,42 mm in the tests at 20°C.

The measured displacements as a function of time are shown in semi-log scale in Fig. 1.1 (ϑ= 20°C, N_{sust}= 24,9 kN). The initial displacements measured shortly after applying the load of 24,9 kN (20°C) scatter considerably. The initial displacement of test 5 is unusual large (test 5: s_0= 0,67 mm; remaining tests: s_0= 0,31 mm to 0,47 mm, on average 0,36 mm).

In a linear scale the displacements are shown in Fig. 1.2 (ϑ= 20°C). In those figures the approximation of the creep curves according to the Findley approach are also shown. Fig. 1.3 (ϑ= 20°C) show the extrapolation to the intended service life (50 years at standard temperature). The extrapolated displacements exceed the limit value according to [G1]. However, in the tests at 20°C the initial displacement of test 5 is unusual large. Therefore in Fig. 1.4 (ϑ= 20°C) the creep curve of test 5 was

shifted that the curve starts at the average initial displacement of the remaining tests ($s_{0,m}$= 0,36 mm).

The extrapolated displacements are summarized in Table 1.1 for tests at ϑ= 20°C. The criterion for the displacement is fulfilled if the initial displacement of test 5 is corrected to the average initial displacement of the remaining tests (Fig. 1.4).

Following the sustained load tests confined tension tests were performed. The results are evaluated in Table 2.1. The value α_{req}= 0,90 must be maintained. The failure loads of the tests conducted at ϑ= 20°C fulfil the requirements according to [G1].

test	ϑ °C	N_{sust} kN	τ_{sust} N/mm²	$\delta_{50years}$ [1] mm	$\delta_{50years,m}$ [2] mm	Δ_{limit} [3] mm	$\delta_{50years,max}$ [4] mm	1,2 Δ_{limit} mm	Criterion
1	20	24,9	12,8	0,94	(1,34) 1,27	1,42	(1,94) 1,64	1,70	(--) ok
2				1,31					
3				1,36					
4				1,14					
5				(1,94) 1,64[5]					

1) Displacement extrapolated to t= 50 years with Findley approach of single test
2) Average extrapolated displacement
3) Average displacement of load at loss of adhesion, established for 2-point measurement
4) Maximum extrapolated displacement
5) Extrapolated displacement corrected for initial displacement as average value of remaining tests

Table 1.1 Evaluation of extrapolated displacements in sustained load tests at standard temperature (ϑ= 20°C)

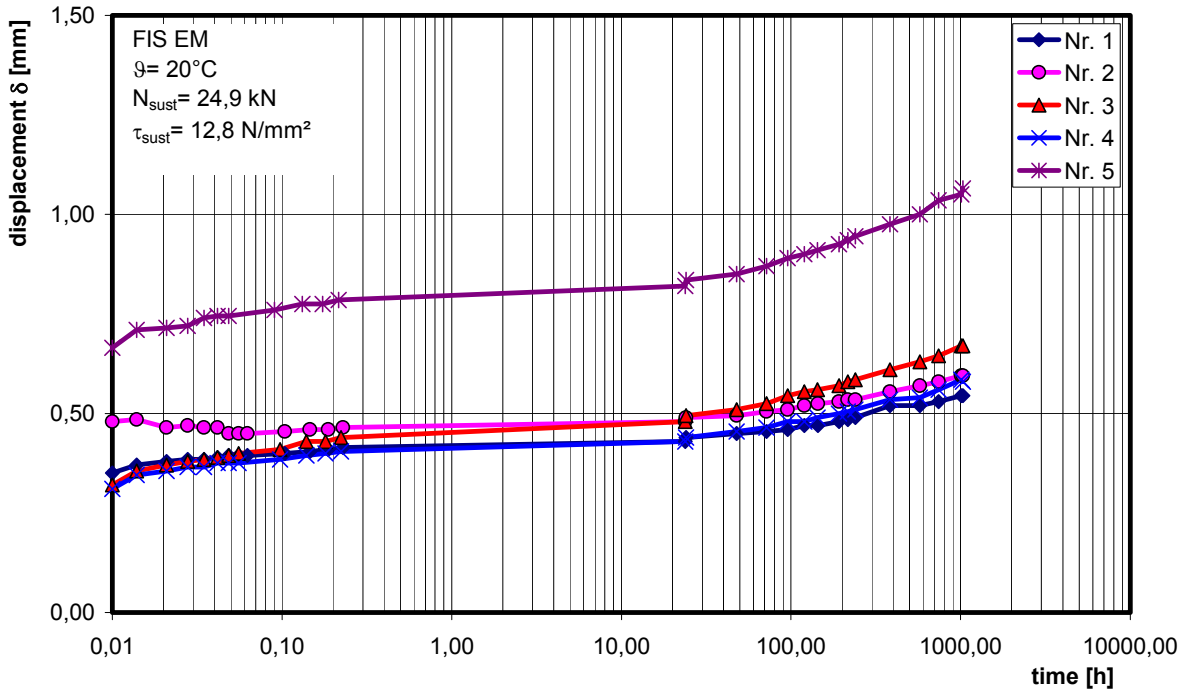

Fig. 1.1: Displacements of anchors at ϑ = 20°C in semi-logarithmic scale, load duration 1.031 h, Fischer FIS EM, size M10

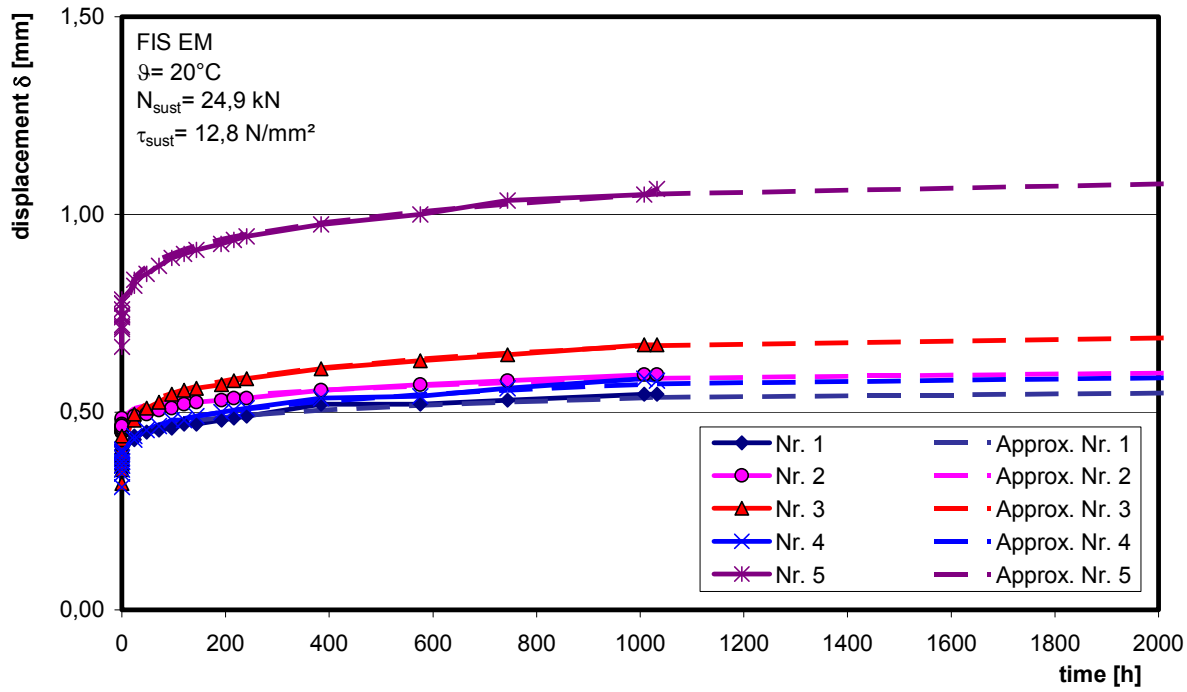

Fig. 1.2: Displacements of anchors at ϑ = 20°C in linear scale with approximation according to Findley approach, load duration 1.031 h, Fischer FIS EM, size M10

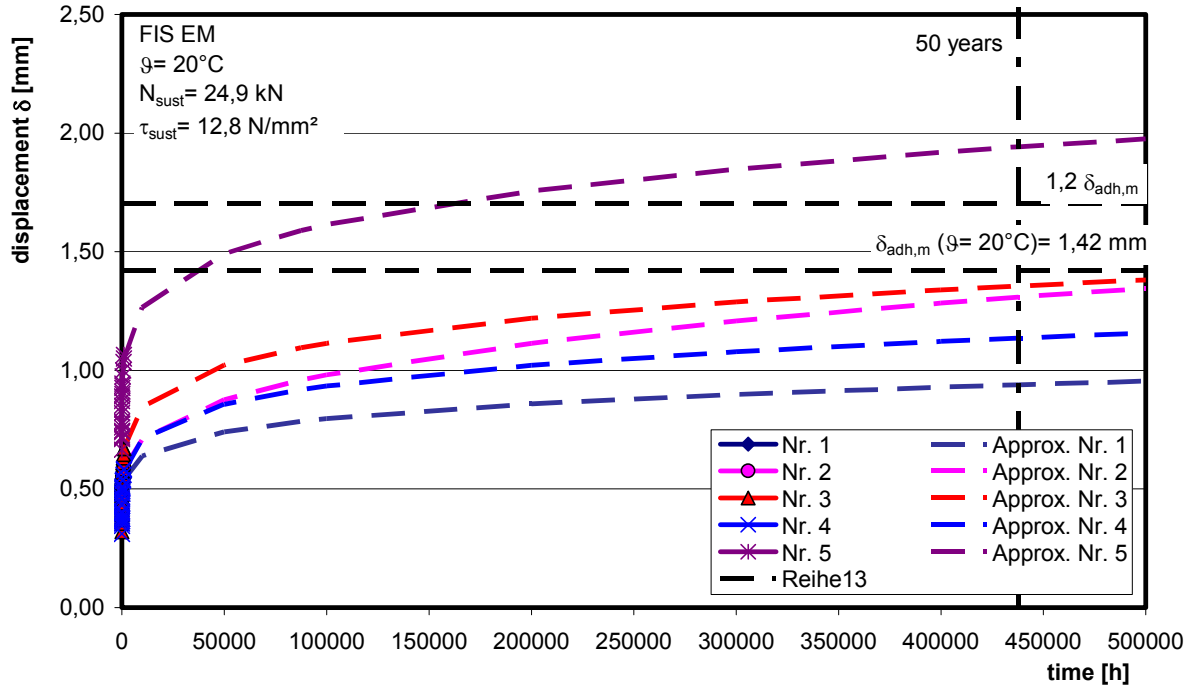

Fig. 1.3: Displacements of anchors at ϑ = 20°C in linear scale with approximation according to Findley approach, load duration 1.031 h, Fischer FIS EM, size M10

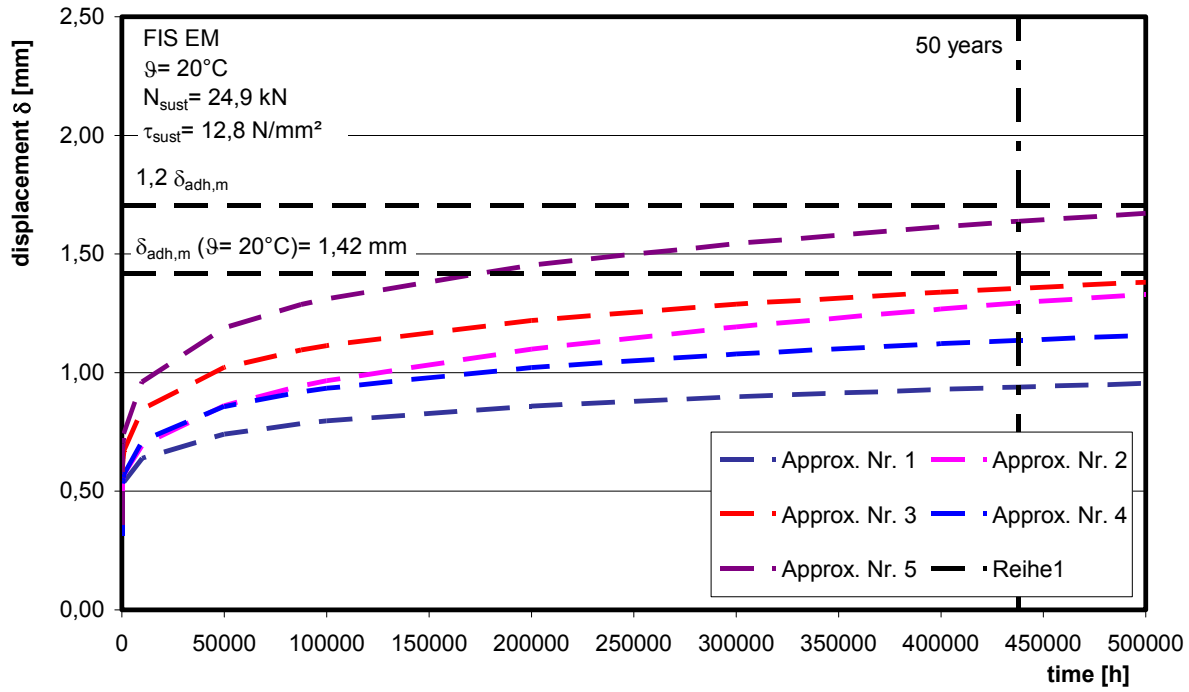

Fig. 1.4: Displacements of anchors at ϑ = 20°C in linear scale with approximation according to Findley approach, load duration 1.031 h, Fischer FIS EM, size M10, displacement of test 5 corrected

If you have any further questions please contact us.

Sincerely yours

Dr.-Ing. T. Pregartner

2 References

[G1] AC308: Acceptance criteria for post installed adhesive anchors in concrete approved February 2007, effective March 2007

[G2] AC308: Acceptance criteria for post installed adhesive anchors in concrete, approved June 2006, proposed May 2007

							Test results								Reference values			Comparison			
Series	N_{sust}	ϑ	Size	h_{ef} [1]	$f_{c,cyl}$	Test member	n	F_{um} [2]	V [2]	Failure [3]	$\tau_{u,m}$ [4]	V [4]	Lab [5]	$\tau_{u,k,17}$ [7]	$\tau_{o,i}$ [8]	$\tau_{k,o,,i}$ [8]	V [8]	$\alpha = \tau_{u,m,17}/\tau_{o,i}$	$\alpha = \tau_{u,k,17}/\tau_{k,o,i}$	α_{req} [9]	$\alpha' = \alpha/\alpha_{req}$
	kN	°C		mm	N/mm²			kN	%		N/mm²	%		N/mm²	N/mm²	N/mm²	%				
Reference	-	20	M10	61,6	25,1	270307	5	59,9	4,8	$3*P/P_M, 1*P/P_{M,RC}$	31,0	5,4	IWB	25,3							
Sustained load	24,9	20	M10	61,8	27,6	270307	5	63,9	4,9	$5*P/P_{M,RC}$	32,9	4,4	IWB	28,0	31,0	25,3	5,4	1,06	1,1	0,9	1,00

1) Average embedment depth of the conducted tests
2) Measured average failure load and corresponding coefficient of variation
3) P= Pullout without mortar; P_M = Pullout with mortar; RC = Radial cracking outgoing from anchor; S = steel failure
4) Average bond strength and corresponding coefficient of variation calculated from the single failure loads and the measured embedment depth
5) Independent test lab IWB
6) $\tau_{u,17} = \tau_{u,m} \cdot (17/f_{c,cyl})^{0,13}$
7) Calculated assuming an unknown standard deviation (p= 90%)
8) Bond strength $\tau_{u,17}$ of reference test conducted in the same concrete slab
9) Required value according to [G1]

Table 2.1 Evaluation of the residual tension capacity of the tests for the assessment of the influence of sustained loads, confined tests in non cracked concrete, size M10