TECHNICAL REPORT

Assessment of torque-controlled bonded anchors

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Foreword

EOTA Technical Reports are developed as supporting reference documents to European Technical Approval Guidelines and can also be applicable to a Common Understanding of Assessment Procedures, an EOTA Comprehension Document or an European Technical Approval, as far as reference is made therein.

EOTA Technical Reports go into detail in some aspects and express the common understanding of existing knowledge and experience of the EOTA bodies at a particular point in time.

Where knowledge and experience is developing, especially through approval work, such reports can be amended and supplemented.

When this happens, the effect of the changes upon the European Technical Approval Guidelines will be laid down in the relevant comprehension documents, unless the European Technical Approval Guideline is revised.

This EOTA Technical Report has been prepared by the EOTA Working Group 06.01/03 – "Metal anchors for use in concrete" and endorsed by EOTA.

1 General

Torque-controlled bonded anchors are installed in cylindrical holes, the load transfer is realised e.g. by mechanical interlock of a cone or several cones in the bonding mortar and then via a combination of bonding- and friction forces in the anchorage ground (concrete).

When a tension force of a certain magnitude is acting in the anchor rod the adhesion between mortar and anchor rod is destroyed.

After this bonding has been destroyed the expansion areas, due to their geometry, cause expansion forces as in the case of expansion anchors, which press the bonding mortar to the wall of the drilled hole; thus the bonding mortar is expanded or bursts, i.e. it takes over the function of an expansion sleeve of torque-controlled expansion anchors.

In non-cracked concrete the loadbearing effect of the bonding by friction is increased due to the expansion forces. In cracked concrete an extensive loss of adhesion between mortar and concrete is likely to occur.

In this case torque-controlled bonded anchors act like torque-controlled expansion anchors corresponding to Part 2 of ETAG 001.

The assessment of the suitability of torque-controlled bonded anchors shall be performed on the basis of suitability tests according to Part 2 and Part 5 of ETAG 001 with corresponding modifications and adaptations being made (see clause 2).

The function of the anchors is ensured, if during loading the adhesion between anchor rod and mortar is destroyed at a level which is lower than the holding capacity of the bond between mortar and drill hole wall.

The admissible service conditions are determined on the basis of tests according to Annex B of ETAG 001 as for usual torque-controlled expansion anchors.

Additionally, the influences of temperature and durability on the bonding mortar shall be determined according to Part 5 of ETAG 001 (see clause 2.2.2).

2 Required tests and their assessment

2.1 Tests for suitability

2.1.1 General

Table 5.1.1 and 5.1.2 contain the required suitability tests for torque-controlled bonded anchors.

If the slip and bond force tests are carried out and the requirements according to clause 2.1.6 are fulfilled, then Table 5.1.1 is valid. Table 5.1.2 is used if the conditions according to clause 2.1.6 are not fulfilled or the slip and bond force tests are not carried out.

If Table 5.1.1 should be used it is recommended that first the tests are carried out according to Table 5.1.1, line 10 and 11 with checking of the requirements to clause 2.1.6.

If these requirements are not fulfilled, then the tests according to Table 5.1.2 shall be performed.

The test procedures given in line 1 to 9 in both Tables correspond in principle to the required tests for bonded anchors according to Part 5 of ETAG 001, Table 5.1, the necessary modifications and adaptations (also the number of tests) are given in the following.

In Part 5, clause 5.1, it is required that the test programme is carried out in concrete made from different concrete batches to take account of the possible influence of different concrete compositions on the bond behaviour.

	Purpose of test	Concrete	T/T_{inst}	Crack width Δw	Minimum number of tests for anchor size (1)					Criteria		Test procedure
				(mm)	s	i	m	i	l	load/disbehav.	req. α (2)	Part 5 (7)
1	Installation safety - (a1) dry concrete (5)	C 20/25	0.5	0,3	5	-	5	-	5	Part 1, 6.1.1.1 (a) to (c)	$\geq$ 0,8 (3)	5.1.2.1 (a)
	(a2) dry concrete (6) (8)	C 20/25	1.0/0.5 (4)	0,3	5	-	5	-	5		$\geq$ 0,8(3)	5.1.2.1 (a)
	(b) wet concrete (6) (8)	C 20/25	1.0/0.5 (4)	0,3	5	-	5	-	5		$\geq$ 0,75 (3)	5.1.2.1 (b)
	(c) flooded hole installation (6)	C 20/25	1.0/0.5 (4)	0,3	5	-	5	-	5		$\geq$ 0,75 (3)	5.1.2.1 (c)
	(d) mixing technique	C 20/25	1.0/0.5 (4)	0,3	-	-	5	-	-		$\geq$ 0,8 (3)	5.1.2.1 (d)
3	Functioning in low strength concrete	C 20/25	1.0/0.5 (4)	0,5	5	-	5	-	5		$\geq$ 0,8	5.1.2.2
4	Functioning in high strength concrete	C 50/60	1.0/0.5 (4)	0,5	5	-	5	-	5		$\geq$0,8	5.1.2.2
5	Functioning in crack movements	C 20/25	1.0/0.5 (4)	0,1 - 0,3	5	5	5	5	5	Part 1, 6.1.1.1; 6.1.1.2 a)	$\geq$ 0,9	5.1.2.3
6	Functioning under sustained loads	C 20/25	1.0/0.5 (4)	0	-	-	5	-	-	Part 5, 6.1.1.2 (e)	$\geq$ 0,9	5.1.2.5
7	Maximum torque moment	C 50/60	$\geq$ 1.3	0	5	5	5	5	5	Part 1, 6.1.1.2 (d)		5.1.2.6
8	Functioning under freeze/thaw cond.	C 20/25	1.0/0.5 (4)	0	-	-	5	-	-	Part 5, 6.1.1.2 (f)	$\geq$ 0,9	5.1.2.7
9	Functioning with installation direction	C 20/25	1.0/0.5 (4)	0,3	-	-	5	-	-	Part 5, 6.1.1.2 (g)	$\geq$ 0,9	5.1.2.8
10	slip force test	C 20/25	0	0,3	5	5	5	5	5	see 2.1.4 of this Technical Report		
11	bond force test	C 20/25	0	0,3	5	5	5	5	5	see 2.1.5 of this Technical Report		

1 Anchor size: s = smallest; i = intermediate; m = medium; l = largest; m = M12 or smallest size if that is larger than M12.
If fewer than three anchor sizes are tested together, then the number of tests for line 1 to 5 shall be increased to 10 for all anchor sizes. If anchors are not similar in respect to geometry, friction between cone and mortar sleeve (internal friction) and friction between mortar sleeve and concrete (external friction), then the tests according to line 1 to 4 shall be performed with all sizes.

2 α see Part 1, Equation (6.2)

3 Valid for $\gamma_2 = 1.2$, for other values of γ_2 refer to Part 5, clause6.1.2.2.2

4 10 minutes after applying the torque moment T_{inst}, the torque moments shall be reduced to $T = 0.5\ T_{inst}$. If no torque moment recommended, all tests shall be carried out without torque moment.

5 In contrast to Part 5, clause 5.1.2.1(a) the hole shall be cleaned according to the manufacturer's installation instructions

6 Cleaning of the hole as described in Part 5, clause 5.1.2.1(b) and (c).

7 Tests procedure according to ETAG 001, Part 5; tests in line 1 to 5 and 9 as unconfined tests and in cracked concrete.

8 If there is experience about the behaviour of the mortar in dry and wet concrete, then one of the test series (a2) or (b) may be deleted.

Table 5.1.1 - Suitability tests for torque-controlled bonded anchors to be used in cracked and non-cracked concrete with checking the principle of functioning

If with torque-controlled bonded anchors concrete cone or pull-through failure occurs, then the test programme has not to be carried out in concrete made from different concrete batches, because possible deviations in the concrete batches have little influence on the failure load.

However, if in a test pullout failure (pullout of anchor rod with mortar) occurs, the influence of different concrete batches has to be considered according to Part 5.

In contrast to Part 5, clause 5.1.2, all tests in lines 1 to 5 and line 9 shall be carried out as unconfined tests in cracked concrete. The results of these suitability tests shall be compared with the results of tests according to Part 1, Table 5.4, line 3 (tests in C20/25) or line 4 (tests in C50/60) respectively for admissible service conditions.

The reference tests according to Part 5, 5.1.1, need not be carried out.

The results of tests according to line 6 and 8 shall be compared with confined reference tests performed in the same concrete batch. For the determination of the α-factor the relations given in Part 1, clause 6.1.1.1 d) shall be used.

All suitability tests shall be carried out with drill bits with a medium cutting diameter $d_{cut,m}$. In the tests the torque moments T_{inst} recommended by the manufacturer (with the exception of the tests according to line 1(a) and 7 in the Tables) shall be applied.

Ten minutes after applying the torque moment it shall be reduced to 0,5 T_{inst}. If no torque moment is given by the manufacturer, the tests shall be carried out without torque moment.

	Purpose of test	Concrete	T/T_{inst}	Crack width Δw	Minimum number of tests for anchor size (1)					Criteria		Test procedure
				(mm)	s	i	m	i	l	load/disbehav.	req. α (2)	Part 5 (7)
1	Installation safety - (a1)dry concrete(5)	C 20/25	0.5	0,3	10	10	10	10	10	Part 1 - 6.1.1.1 (a) to (c)	$\geq$ 0,8(3)	5.1.2.1 (a)
	(a2)dry concrete (6) (8)	C 20/25	1.0/0.5 (4)	0,3	10	10	10	10	10		$\geq$ 0,8(3)	5.1.2.1 (a)
	(b)wet concrete (6) (8)	C 20/25	1.0/0.5 (4)	0,3	10	10	10	10	10		$\geq$ 0,75 (3)	5.1.2.1 (b)
	(c) flooded hole installation (6)	C 20/25	1.0/0.5 (4)	0,3	10	10	10	10	10		$\geq$ 0,75 (3)	5.1.2.1 (c)
	(d) mixing technique	C 20/25	1.0/0.5 (4)	0,3	-	-	10	-	-		$\geq$ 0,8 (3)	5.1.2.1 (d)
3	Functioning in low strength concrete	C 20/25	1.0/0.5 (4)	0,5	10	10	10	10	10		$\geq$ 0,8	5.1.2.2
4	Functioning in high strength concrete	C 50/60	1.0/0.5 (4)	0,5	10	10	10	10	10		$\geq$0,8	5.1.2.2
5	Functioning in crack movements	C 20/25	1.0/0.5 (4)	0,1 - 0,3	10	5	10	5	10	Part 1 - 6.1.1.1 6.1.1.2 a)	$\geq$ 0,9	5.1.2.3
6	Functioning under sustained loads	C 20/25	1.0/0.5 (4)	0	-	-	5	-	-	Part 5 - 6.1.1.2 (e)	$\geq$ 0,9	5.1.2.5
7	Maximum torque moment	C 50/60	$\geq$ 1.3	0	5	5	5	5	5	Part 1 - 6.1.1.2 (d)		5.1.2.6
8	Functioning under freeze/thaw cond.	C 20/25	1.0/0.5 (4)	0	-	-	5	-	-	Part 5 - 6.1.1.2 (f)	$\geq$ 0,9	5.1.2.7
9	Functioning with installation direction	C 20/25	1.0/0.5 (4)	0,3	-	-	5	-	-	Part 5 - 6.1.1.2 (g)	$\geq$ 0,9	5.1.2.8

1 Anchor size: s = smallest; i = intermediate; m = medium; l = largest; m = M12 or smallest size if that is larger than M12. If fewer than three anchor sizes are tested together and /or the different anchor sizes are not similar in respect to geometry, friction between cone and mortar sleeve (internal friction) and friction between mortar sleeve and concrete (external friction), then the number of tests for line 1 to 5 shall be doubled for all anchor sizes.

2 α see Part 1, Equation (6.2)

3 Valid for γ_2 = 1.2, for other values of γ_2 refer to Part 5, clause 6.1.2.2.2

4 10 minutes after applying the torque moment T_{inst}, the torque moments shall be reduced to T = 0.5 T_{inst} . If no torque moment recommended, all tests shall be carried out without torque moment.

5 In contrast to Part 5, clause 5.1.2.1(a) the hole shall be cleaned according to the manufacturer's installation instructions

6 Cleaning of the hole as described in Part 5, clause 5.1.2.1(b) and (c).

7 Tests procedure according to ETAG 001, Part 5; tests in line 1 to 5 and 9 as unconfined tests and in cracked concrete.

8 If there is experience about the behaviour of the mortar in dry and wet concrete, then one of the test series (a2) or (b) may be deleted.

Table 5.1.2 - Suitability tests for torque-controlled bonded anchors to be used in cracked and non-cracked concrete without checking the principle of functioning

2.1.2 Installation safety

In general, the installation safety tests in Table 5.1.1 and 5.1.2, line 1(a) to 1(d) shall be carried out according to Part 5, clause 5.1.2.1, however, they shall be performed in cracked concrete (Δw = 0.3 mm) as unconfined tests.

In the tests according to line 1(a1) the torque moment of 50% of T_{inst} recommended by the manufacturer shall be applied and in contrast to Part 5, clause 5.1.2.1(a), the hole shall be cleaned according to the manufacturer's installation instructions.

2.1.3 Functioning with installation direction

These tests shall be carried out in cracked concrete Δw = 0.3 mm as unconfined tests.

2.1.4 Slip force tests

The tests according to Table 5.1.1, line 10 are carried out to determine the slip force.

The slip force is that force, at which the adhesion between anchor rod and mortar is destroyed.

The slip force may be determined by a significant change in the stiffness of the load-displacement curve and/or a clear increase of the splitting force.

At least 5 tests per anchor size shall be carried out.

The mean slip force ($F_{slip,m}$) and the 95%-fractile of the slip force ($F_{slip95\%}$) shall be determined for each anchor size with a confidence level of 90 % and by assuming an unknown standard deviation.

Example for slip force tests

The anchor is installed into concrete C 20/25 with the hole cleaning recommended by the manufacturer.

No torque moment shall be applied.

After opening of the cracks up to Δw = 0.3 mm the anchor is loaded until failure occurs.

The relative displacement of the anchor rod related to the concrete is measured by means of an inductive displacement transducer on the anchor side opposite to the load (unloaded end of the rod).

2.1.5 Bond force tests

The tests according to Table 5.1.1, line 11, are carried out to determine the bond forces by taking account of the most unfavourable anchorage ground conditions.

The bond force is defined as load at loss of adhesion between mortar and wall of the drill hole.

The tests are carried out in cracked concrete C 20/25 Δw = 0.3 mm using an anchor rod which generates no expansion forces (e.g. normal threaded rod with a comparable diameter and length) instead of the anchor rod which is intended for the torque-controlled bonded anchor.

No torque moment is applied.

The hole cleaning is carried out according to the envisaged use category referred to in Part 5, clause 5.1.2.1.

At least 5 tests per anchor size are carried out with one of the condition according Part 5, clause 5.1.2.1a) or b) or c) which gives the worst results.

If no pre-information for this condition is available, then the worst condition is determined by 5 tests with the largest anchor size and the conditions according to Part 5, clause 5.1.2.1a), b) and c).

The determination of the loads at loss of adhesion shall be done according to Part 5, clause 6.1.1.1(a).

The loads shall be converted to $f_c = f_{ck}$ for C20/25 (f_{ck} = 25 N/mm^2 if concrete strength measured on cubes with a side length of 150 mm).

If no general knowledge for the product in question is available the conversion may be done with $f_c^{0.3}$.

The mean bond force (min $F_{bond,m}$) and the 5%-fractile of the bond force ($F_{bond5\%}$) shall be determined for each anchor size with a confidence level of 90% by assuming an unknown standard deviation.

2.1.6 Requirements for the use of Table 5.1.1

The test program according to Table 5.1.1 may be applied, if one of the following requirements is met:

$F_{bond,m} / F_{slip,m} \geq 3.0$; (2.1) or

$F_{bond5\%} / F_{slip95\%} \geq 1.3$; (2.2)

$F_{bond,m}$ = mean bond force;

$F_{slip,m}$ = mean slip force;

$F_{slip95\%}$ = 95%-fractile of the slip force;

$F_{bond5\%}$ = 5%-fractile of the bond force.

Under the assumption of a normal distribution of the bond forces and slip forces and unknown standard deviations the two conditions ensure that the slip forces will not exceed the bond forces with a probability in the order of 10^{-3}.

The two conditions given above are considered as being equivalent, if the coefficient of variation of the tests is ≤ 15% (tests according to Table 5.1.1, line 10) and ≤ 10% (tests according to Table 5.1.1, line 11).

If the coefficient of variation is larger in a test series with a particular anchor sizes, than the number of tests in this series should be increased or the ratios in Equations (2.1) or (2.2) should be increased.

If the above requirements are not met or the slip and bond force tests are not performed then Table 5.1.2 applies.

2.1.7 Load displacement behaviour

Load displacement curves of torque-controlled bonded anchors in cracked concrete may show a short plateau (max length about 0,5 mm) and also in some cases a very small decrease of the load.

This behaviour indicates the point when the adhesion between mortar and anchor rod is destroyed.

It is typical for this kind of anchor in cracked concrete. It cannot be interpreted as uncontrolled slip, therefore it is acceptable.

2.2 Tests for the determination of the admissible service conditions

2.2.1 General

The test conditions are given in Part 1, clause 5.1.3, and in Annex B.

For the different concrete batches clause 2.1.1 applies.

All tests shall be carried out as so-called unconfined tests.

All tests shall be carried out with a medium cutting diameter of drill bit $d_{cut,m}$.

Torque moments T_{inst} can be applied by taking account of the footnote (4) of Table 5.1.1 or 5.1.2.

The required additional tests for assessing the influence of temperature and durability on the mortar are set out in the following.

For the evaluation of the load displacement curves clause 2.1.7 shall be taken into account.

2.2.2 Influence of temperature and durability

The tests for assessing the influence of temperature on the loadbearing behaviour of the anchor shall be carried out according to Part 5, clause 5.1.3.1 with anchors of medium size applied for.

For comparison, test in non-cracked concrete of the same batch shall be carried out.

For the assessment of the durability the so-called slice tests with an anchor rod which generates no expansion forces (e.g. with a normal threaded rod) according to Part 5, clause 5.1.4, shall be carried out.

In contrast to Part 5, clause 6.1.3, where the required α_4 is 1.0 the required α_4 for torque controlled bonded anchors for use in cracked concrete is 0.9.

The required α_4 for use in non-cracked concrete remains 1.0.

The evaluation of the above tests shall be carried out according to the relevant sections of Part 5, clause 6.1.2.1(d) to (g) and according to clause 6.1.3 of Part 5.

2.2.3 Determination of the characteristic resistances

The determination of the characteristic resistance shall <u>not</u> be based on Part 5, clause 6.1.2.2.1(a), but on the specifications for usual torque-controlled expansion anchors given in Part 1, clause 6.1.2.2.1.

However possible influence of temperature and/or durability of the mortar on the characteristic resistance shall be taken into account according to Part 5, Equation (6.20) and the possible influence of concrete batches on the characteristic resistance shall be evaluated analogous to Part 5, Equation (6.18).