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ETAG 001

GUIDELINE FOR EUROPEAN TECHNICAL APPROVAL OF METAL ANCHORS FOR USE IN CONCRETE

Part four: DEFORMATION-CONTROLLED EXPANSION ANCHORS

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INTRODUCTORY NOTES

In this Part requirements, criteria and test information additional to Part 1 and applicable only to deformation-controlled expansion anchors are given. The same numbering of paragraphs as in Part 1 is used. If a paragraph is not mentioned, then the text in Part 1 applies without modification.

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2 SCOPE

2.1 Anchors

2.1.1 Types and operating principles

In addition to the definition of deformation-controlled expansion anchors given in Part 1, 2.1.1 the following conditions are valid:

- expansion is achieved by the action of installing the anchor, the value of expansion is not intended to change by loading the anchor
- anchors are installed in cylindrical drill holes. Expansion forces are created during anchor installation and tension forces are transferred into the concrete mainly by friction.

Deformation-controlled expansion anchors are installed by hammer blows or by percussion of a machine.

The correct expansion according to manufacturer's installation specification shall be checkable after installation.

This Guideline covers the following types of deformation-controlled expansion anchors:

- cone-down type anchor (drop-in anchor, Figure 2.1(a))
- shank-down type anchor (stud anchor, Figure 2.1(b))
- sleeve-down type anchor (Figure 2.1(c))
- sleeve-down type anchor (stud version, Figure 2.1(d))

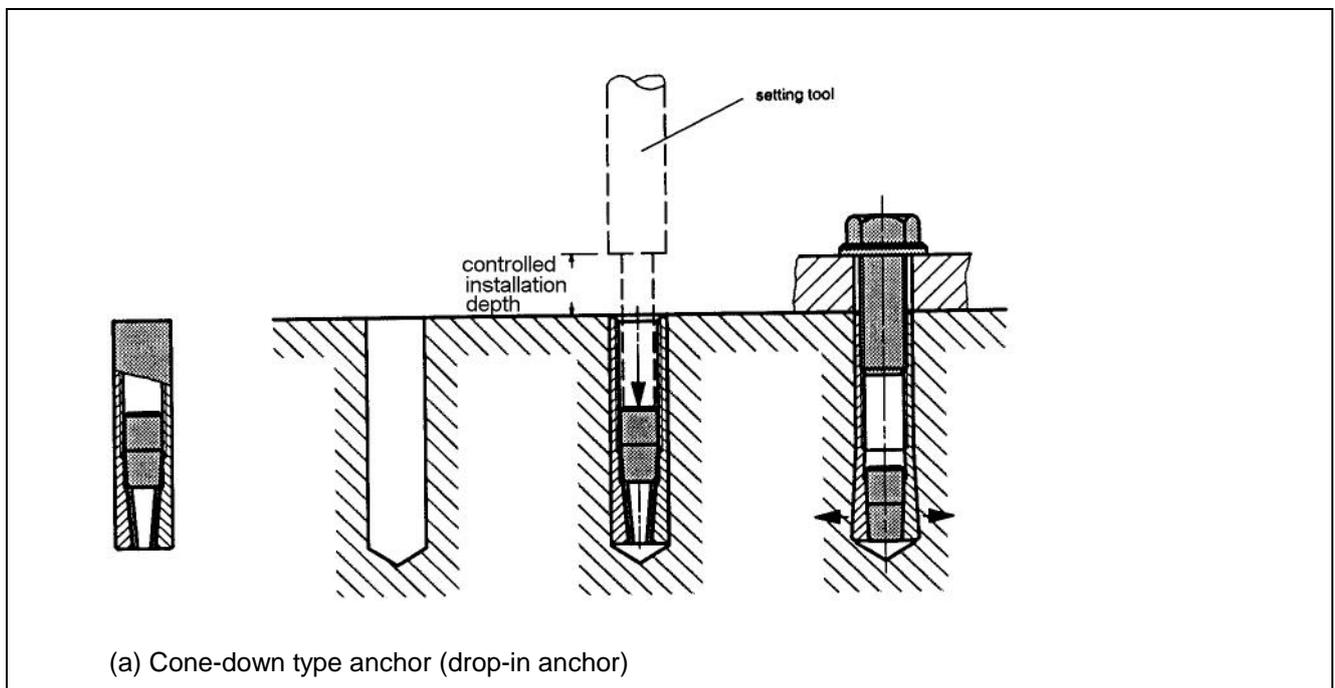


Figure 2.1 Examples of deformation-controlled expansion anchors

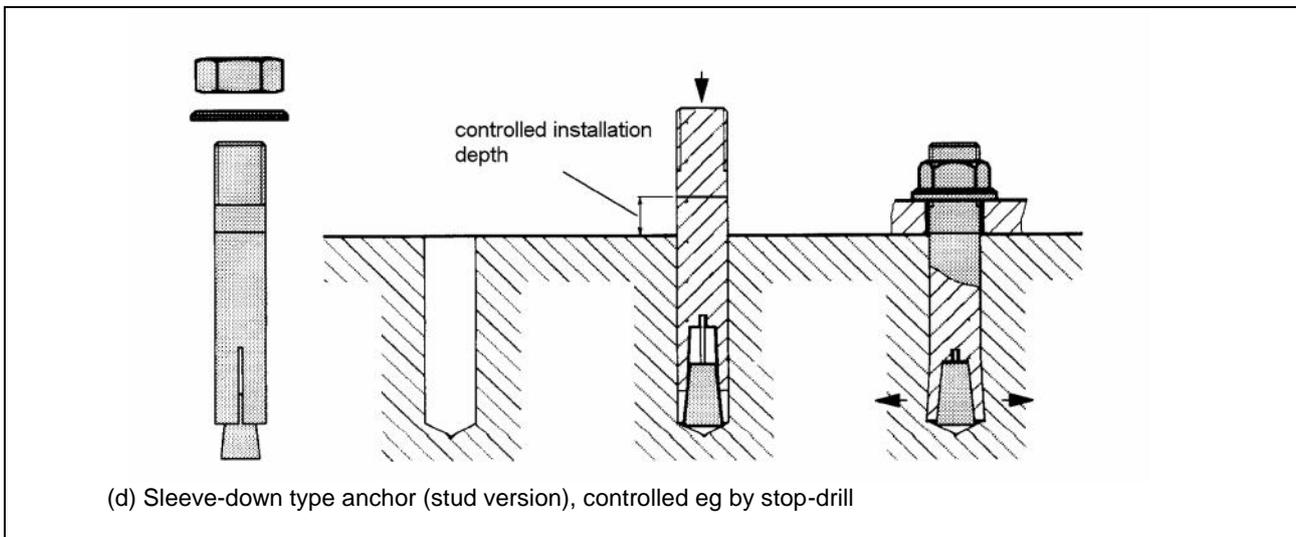
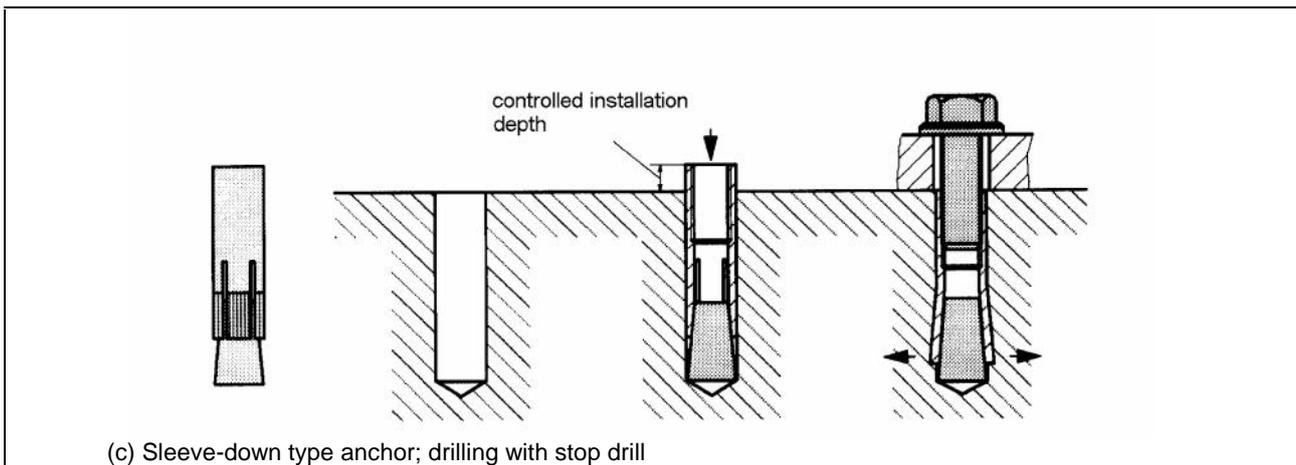
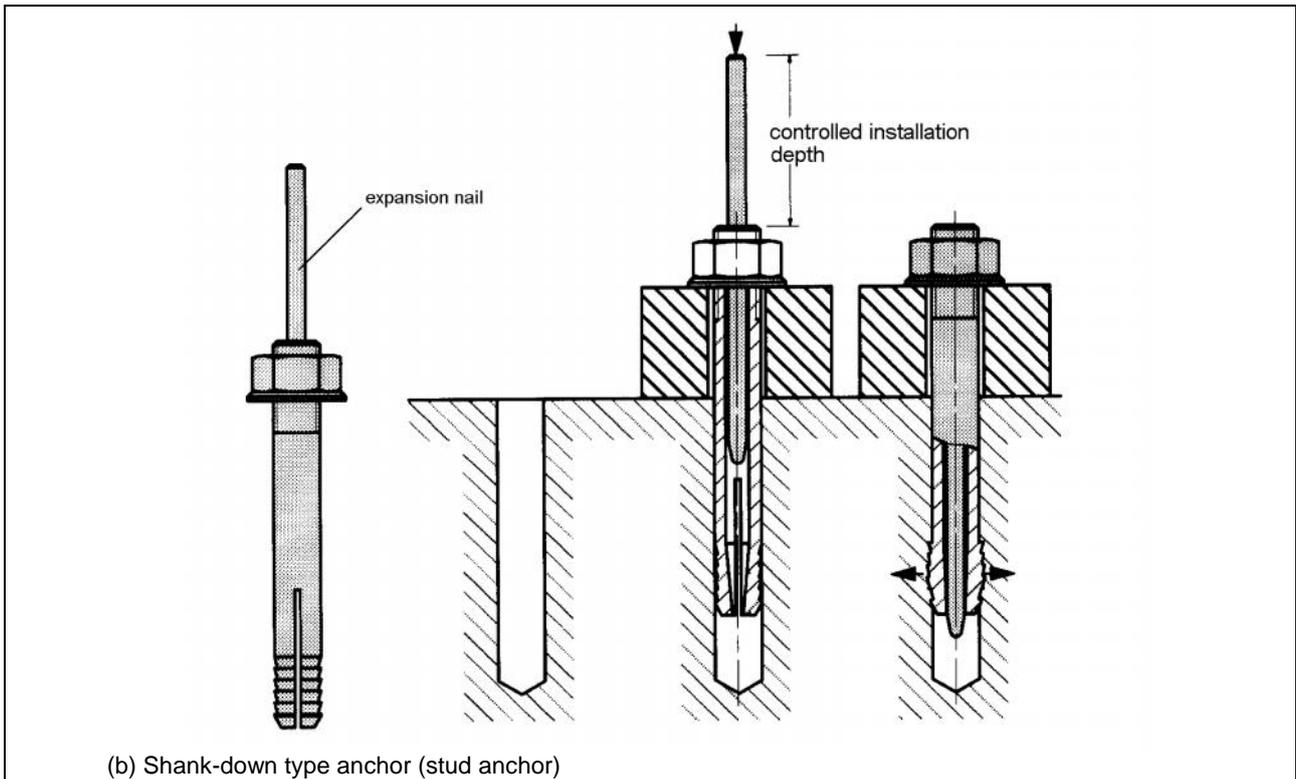


Figure 2.1 Examples of deformation-controlled expansion anchors

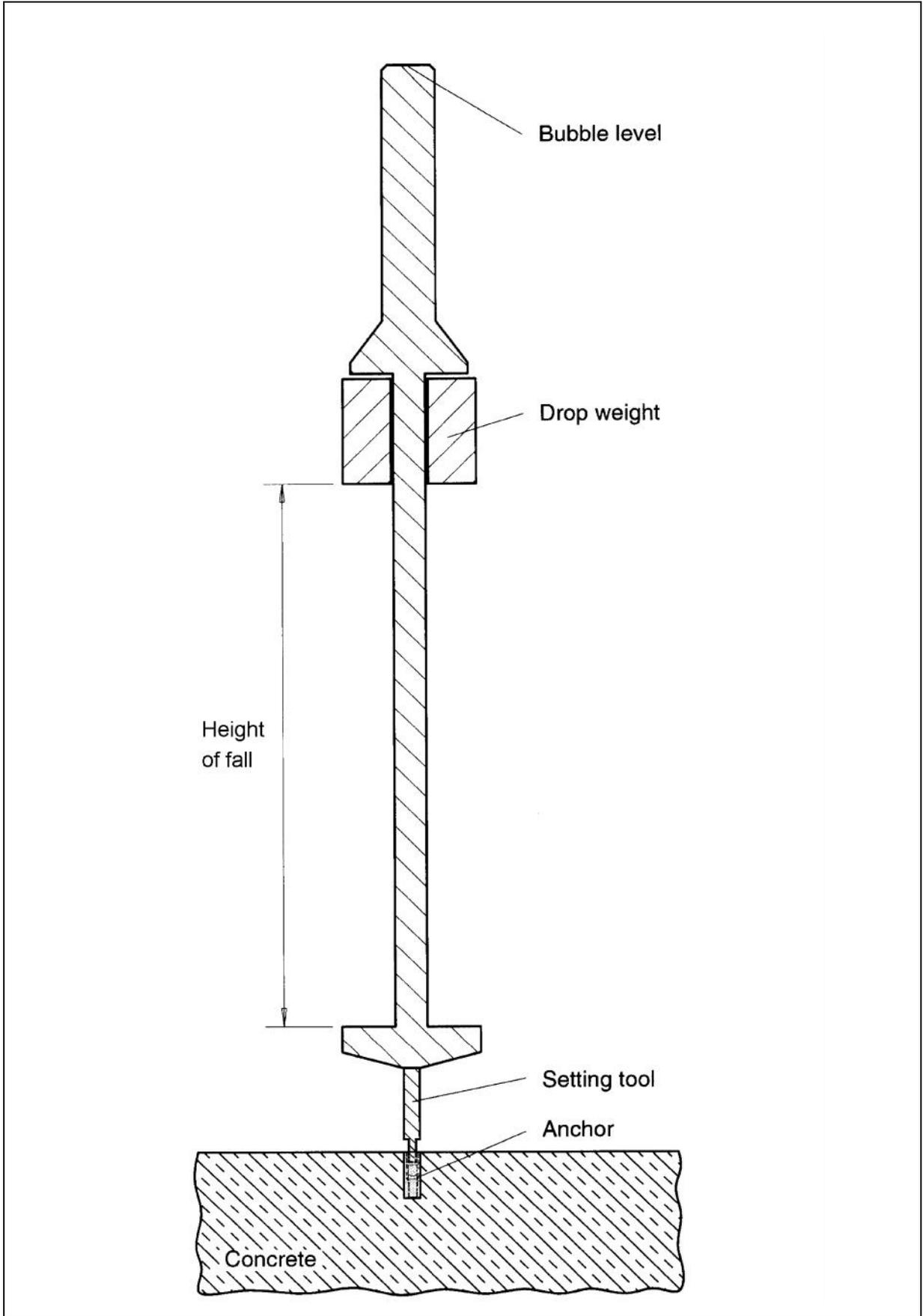


Figure 5.0: Arrangement for setting tests (schematic) (setting of drop-in anchors is shown)

3 TERMINOLOGY

3.2 Particular terminology and abbreviations

3.2.1 General

Full expansion:

Expansion achieved when setting the anchor according to the manufacturer's written installation instructions. Full expansion is used in the tests for determination of admissible service conditions.

Reference expansion:

Expansion achieved by applying a specified expansion energy (see Table 5.0, line 5). The reference expansion is used in the suitability tests.

Installation expansion:

Expansion achieved by applying a specified expansion energy which is reduced in relation to reference expansion (see Table 5.0, line 6). The installation expansion is used in the installation safety tests.

4 REQUIREMENTS FOR WORKS

4.1 Mechanical resistance and stability (ER 1)

4.1.2 Suitability

4.1.2.8 Delivery of unassembled anchors

If the anchors are delivered unassembled to the user, the effect of incorrect assembly of the anchor shall be assessed by the approval body.

5 METHODS OF VERIFICATION

5.1 Methods related to 4.1 (mechanical resistance and stability)

5.1.2 Tests for suitability

5.1.2.1 General

The types of tests, test conditions and the number of required tests, and the criteria applied to the results, are given in Tables 5.1 (anchors for use in cracked and non-cracked concrete) and 5.2 (anchors for use in non-cracked concrete only). In general, all tests shall be performed with single anchors, without edge and spacing effects, under tension loading.

The anchor behaviour can be sensitive to the degree of expansion. The degree of anchor expansion depends on:

- energy of blows either by hand or machine, including setting tool
- design (material, geometry, tolerances, etc.) of the anchor and the setting tool
- diameter of the drilled hole
- concrete strength class

The influence of these parameters on the anchor behaviour is covered by tests with reference expansion. The reference expansion and the installation expansion are evaluated in setting tests according to the methods given in 5.1.2.2.

5.1.2.2 Setting tests

The setting tests are performed with at least 5 anchors of every size in concrete with a strength class of C50/60, using a drill bit with a diameter of the cutting edge $d_{cut,m}$ in the cast side of a non-cracked concrete member. Prior to expansion the anchors are installed according to the manufacturer's written installation specification.

The expansion of the anchors is achieved by an impact device (e.g. generally in accordance with DIN 18127, issue of November 1997, or with BS 1377: Part 4: 1990), structural shape B and C (see Figure 5.0). The impact device is kept perpendicular to the anchor and the setting tool. The drop mass of the impact device generates the expansion by impacting on the setting tool. Impact device, setting tool and anchor shall be in line to prevent energy losses due to additional friction, e.g. by shortening of the setting device outside the concrete and/or by use of a special device to keep the setting tool in line with the anchor axis.

Before the first blow and at least after the number of blows according to Table 5.0, lines 5 and 6, the anchor expansion shall be measured.

This shall be undertaken by measuring the distance between the outer end of the sleeve and the surface of the cone or nail, respectively, for anchors according to Fig. 2.1 (a) to (c). For anchors according to Fig. 2.1 (d) this can be done by measuring the displacement of the stud in relation to the concrete surface or by measuring the distance of the marking on the anchor to the concrete surface.

The installation expansion is defined as the mean expansion achieved in setting tests with the number of applied blows in accordance with Table 5.0, line 6.

The reference expansion is defined as the mean expansion achieved in setting tests with the number of applied blows in accordance with Table 5.0, line 5.

Table 5.0: Test conditions for setting tests

1	anchor size		M6	M8	M10	M12	M16	M20
2	impact device, type		B	B	B	B	C	C
3	mass	kg	4,5	4,5	4,5	4,5	15	15
4	height of fall	mm	450	450	450	450	600	600
5	number of blows ⁽¹⁾ for evaluation of reference expansion. This expansion is used for tests according to Tables 5.1 and 5.2, lines 2 to 6	--	3	5	6	7	4	5
6	number of blows ⁽¹⁾ for evaluation of installation expansion. This expansion is used for tests according to Tables 5.1 and 5.2, line 1	--	2	3	4	5	3	4
⁽¹⁾ The setting tests are carried out with a standardized device applying a constant energy per blow. In practice, the energy applied during setting of the anchor by a handhammer depends on the anchor size. Therefore the number of blows is different for the different anchor sizes.								

If a manufacturer recommends in the written installation instructions setting by machine, then it is to be shown that the installation and reference expansion achieved in the machine setting test shall be at least equal to the corresponding expansion in the setting test by impact device according to Figure 5.0.

The machine setting tests shall be performed with at least 5 anchors of every size in concrete of strength class C50/60, using a drill bit with a diameter of the cutting edge $d_{cut,m}$ in the cast side of a non-cracked concrete member. The setting shall be undertaken vertically upwards by the setting machine with the smallest energy output of the range of machines defined in the manufacturer's installation specifications. Care shall be taken to

hold the machine in line with the anchor axis. Before the first blow and after a maximum of 10 and 15 seconds of setting time the expansion shall be measured.

The installation expansion is achieved in the setting test by the impact device. In setting tests, using a machine, this expansion shall be achieved on an mean after a setting time of at maximum 10 seconds.

The reference expansion is achieved in the setting test by the impact device. In setting tests, using a machine, this expansion shall be achieved on an mean after a setting time of at maximum 15 seconds.

Table 5.1: Suitability tests for deformation-controlled expansion anchors to be used in cracked and non-cracked concrete

	Purpose of test	Concrete	Crack width Δw (mm)	Drill bit	Applied expansion	Minimum number of tests for anchor size (1)					Criteria		Remark	Test procedure described in
						s	i	m	i	l	load displacement behaviour	ultimate load req. α (3)		
0	Setting test	C50/60	0	$d_{cut,m}$		5	5	5	5	5				5.1.2.2
1	Installation safety - (a) anchorage intensity	C20/25	0,3	$d_{cut,m}$	installation expansion (7)	5	5	5	5	5	Part 1, 6.1.1.1	$\geq 0,8$ (4)	(5), (6)	Annex A, 5.2.1
3		C20/25	0,5	$d_{cut,max}$	reference expansion (7)	5	5	5	5	5		$\geq 0,8$	(5), (6)	Annex A, 5.2.1
4	C50/60	0,5	$d_{cut,min}$	reference expansion (7)	5	5	5	5	5	$\geq 0,8$		(5), (6)	Annex A, 5.2.1	
5	Functioning in crack movements	C20/25	0,1 - 0,3	$d_{cut,max}$	reference expansion (7)	5	5	5	5	5	Part 1, 6.1.1.1 and 6.1.1.2 (a)	$\geq 0,9$	(5), (6)	Annex A, 5.5
6	Functioning under repeated loads	C20/25	0	$d_{cut,m}$	reference expansion (7)	-	-	3	-	-	Part 1, 6.1.1.1 and 6.1.1.2 (b)	$\geq 1,0$	(8)	Annex A, 5.6
7	Maximum torque moment	C50/60	0	$d_{cut,m}$	reference expansion $T \geq 1,3 T_{inst}$ (11)	5	5	5	5	5	-	(9)	(10)	Annex A, 5.10
8	Over-hammering	C20/25	0,5	$d_{cut,m}$	over-hammering (12)	5	5	5	5	5		$\geq 0,8$		

Notes: see page 10

5.1.2.3 Details of suitability tests

The details of the suitability tests are given in Tables 5.1 and 5.2.

Full expansion is achieved by setting the anchor according to the manufacturer's written installation instructions, e.g. for cone-down type anchors (Fig. 2.1a) the shoulder of the setting tool is flush to the surface of the sleeve, for shank-down type anchors (Fig. 2.1b) the expansion nail is flush to the stud surface, for sleeve-down type anchors (Fig. 2.1c) the sleeve is flush to the concrete surface, for sleeve-down type anchors (stud version) (Fig. 2.1d) the marking is flush to the concrete surface.

If the reference expansion and/or installation expansion evaluated in the setting tests is less than full expansion, these values have to be used in the suitability tests. The applied expansion in the different test series is defined in the column „Applied expansion“ of Tables 5.1 and 5.2.

The reference and/or installation expansion can be achieved as follows:

Drop-in anchors according to Fig. 2.1a may be expanded by a setting tool shortened such that when it rests on the sleeve, the distance between cone and outer end of the sleeve required for installation or reference expansion respectively, is ensured.

For stud anchors according to Fig. 2.1b the length of the expansion nail may be shortened such that when the expansion nail is flush with the outer end of the sleeve the travel of the expansion nail required for installation or reference expansion respectively, is ensured.

For anchors according to Figure 2.1 c) and d) the mean value of the actual expansion of the tests according to Tables 5.1 and 5.2, line 1, shall be equal to the installation expansion evaluated according to 5.1.2.2 and the mean value of the actual expansion of the tests according to Tables 5.1 and 5.2, lines 2 to 6, shall be equal to the reference expansion evaluated according to 5.1.2.2.

Table 5.2 Suitability tests for deformation-controlled expansion anchors to be used in non-cracked concrete only

	Purpose of test	Concrete	Drill bit	Applied expansion	Minimum number of tests for anchor size (1)					Criteria		Remark	Test procedure described in
					s	i	m	i	l	load displacement behaviour	ultimate load req. α (3)		
0	Setting test	C50/60	$d_{cut,m}$		5	5	5	5	5				5.1.2.2
1	Installation safety - (a) anchorage intensity	C20/25	$d_{cut,m}$	installation expansion (7)	5	-	5	-	5	Part 1, 6.1.1.1	$\geq 0,8$ (4)	(6), (8)	Annex A, 5.2.1
3		C20/25	$d_{cut,max}$	reference expansion (7)	5	-	5	-	5		$\geq 0,8$	(6), (8)	Annex A, 5.2.1
4	Functioning in high strength concrete	C50/60	$d_{cut,min}$	reference expansion (7)	5	-	5	-	5		$\geq 1,0$	(6), (8)	Annex A, 5.2.1
5	Functioning under repeated loads	C20/25 C50/60	$d_{cut,m}$	reference expansion (7)	-	-	3 3	-	-		Part 1, 6.1.1.1 and 6.1.1.2 (b)	$\geq 1,0$	(8)
6	Functioning under sustained loads	C20/25	$d_{cut,m}$	reference expansion (7)	-	-	4	-	-	Part 1, 6.1.1.1 and 6.1.1.2 (c)	$\geq 1,0$	(8)	Annex A, 5.7
7	Maximum torque moment	C50/60	$d_{cut,m}$	reference expansion $T \geq 1,3 T_{inst}$ (11)	5	5	5	5	5	-	(9)	(10)	Annex A, 5.10
8	Over-hammering	C20/25	$d_{cut,m}$	over-hammering (12)	5	5	5	5	5		$\geq 0,8$		

Notes: see page 10

Notes to Tables 5.1 and 5.2

- (1) Anchor size: s = smallest, i = intermediate, m = medium, l = largest
- (2) Necessary only for anchors with $h_{ef} < 80$ mm to be used in concrete members with a reinforcement of spacing < 150 mm.
- (3) α see Part 1, 6.1.1.1.d.
The values $N_{R_{u,m}}^f$ and $N_{R_k}^f$ in Equation (6.2a,b) are derived from tests for admissible service conditions according to 5.1.3 on single anchors with full expansion without edge and spacing effects loaded in tension. These tests shall be done in cracked concrete when the suitability tests are done in cracked concrete or in non-cracked concrete when the suitability tests are done in non-cracked concrete.
- (4) Valid for $\gamma_2 = 1,2$, for other values of γ_2 see Part 1, 6.1.2.2.2.
- (5) If fewer than three anchor sizes are tested together and/or the different anchor sizes are not similar in respect of geometry, then the number of tests shall be increased to 10 for all anchor sizes.
- (6) If the coefficient of variation of the anchor displacements at a load $F = 0,5 F_{R_{u,m}}$ ($F_{R_{u,m}}$ = mean failure load in a test series) $v \geq 30$ %, then the number of tests in this test series shall be increased to $n = 10$. If the coefficient of variation of the failure loads is $10 \leq v < 20$ % or $20 \leq v \leq 30$ % then the number of tests in this test series shall be increased to $n = 10$ or $n = 20$ respectively.
- (7) Test conditions are given in 5.1.2.2 for evaluation of installation and reference expansion.
- (8) If anchors do not have similar geometry, then other sizes shall also be tested.
- (9) See Part 1, 6.1.1.2(d) with replacing bolt by sleeve.
- (10) The number of sizes to be tested may be reduced or these tests may be omitted if it can be shown by experience that the requirement according to Part 1, 6.1.1.2(d) will be fulfilled.
- (11) In maximum torque moment tests a torque moment of $1,3 T_{inst}$ is required for measuring the prestressing force.
- (12) Tests are required for anchors according to Figure 2.1 c) and d) only. After achieving full expansion of the anchor two more blows shall be applied with the impact device according to Figure 5.0.

5.1.3 Tests for admissible service conditions

The test conditions are given in Part 1, 5.1.3 and Annex B. They are summarized in Table 5.4 of Part 1. Table 5.4 applies to anchors to be used in cracked and non-cracked concrete according to Option 1.

All tests are performed with setting of anchors according to the manufacturer's written installation instructions.

6 ASSESSING AND JUDGING THE FITNESS OF ANCHORS FOR AN INTENDED USE

6.1 Assessing and judging related to 4.1 (mechanical resistance and stability)

6.1.1 Suitability

6.1.1.1 Criteria valid for all tests

(a) Load/displacement behaviour

With deformation-controlled expansion anchors the sleeve can slip in the hole. The differences in static friction and sliding friction can lead to fluctuations in the load/displacement curve as shown in Figure 6.1a (2) and (5). Furthermore in cracked concrete after overcoming the friction resistance the tension load is transferred by mechanical interlock of the expanded anchor, resulting in a much lower anchor stiffness. This may also lead to a reduction of the load taken up by the anchor over a rather short displacement interval as shown in Figure 6.1 a (4) and (5). This cannot be considered as uncontrolled slip.

The ultimate load is the maximum load recorded in the test independently of the displacement.

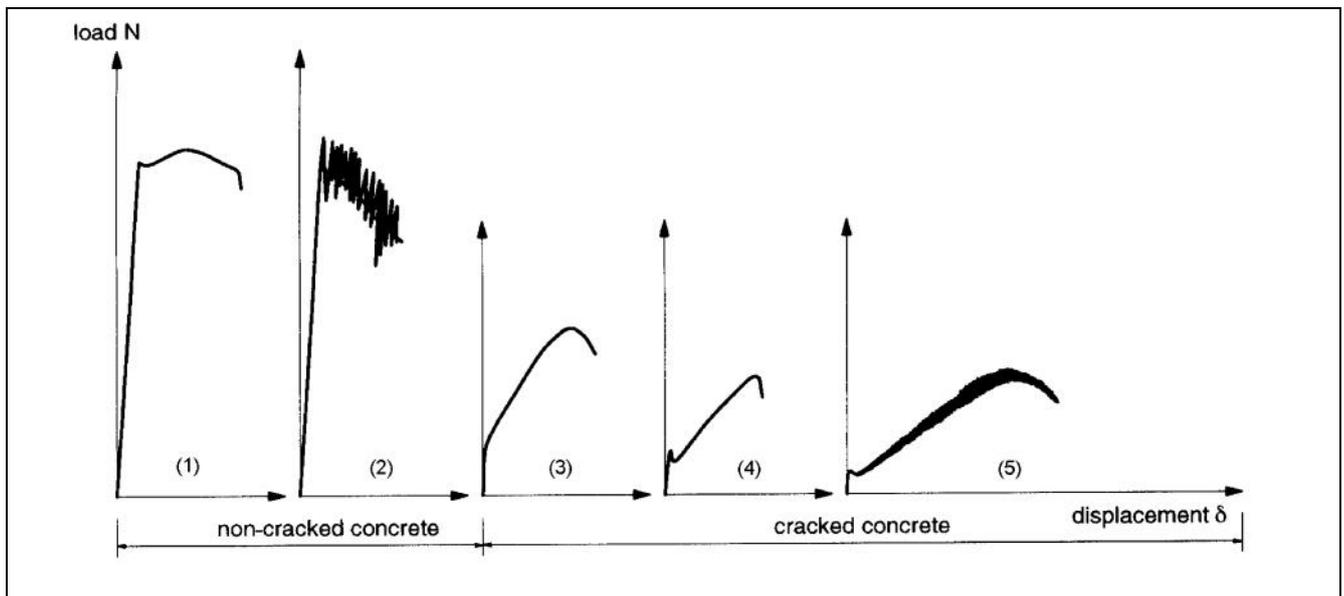


Figure 6.1.a Typical acceptable load/displacement behaviour

Uncontrolled slip of an anchor occurs under sliding friction conditions, when an increase of the load is only generated by inaccuracies of the drilled hole (e.g. change in diameter over its length, off centre over its length).

This can be recognized when the extension of the load/displacement curve is cutting the displacement axis at displacements $\delta \geq 0$ (see Figure 6.1.b). The load N_1 according to Part 1, 6.1.1.1.a is defined by the horizontal branch of the load/displacement curve.

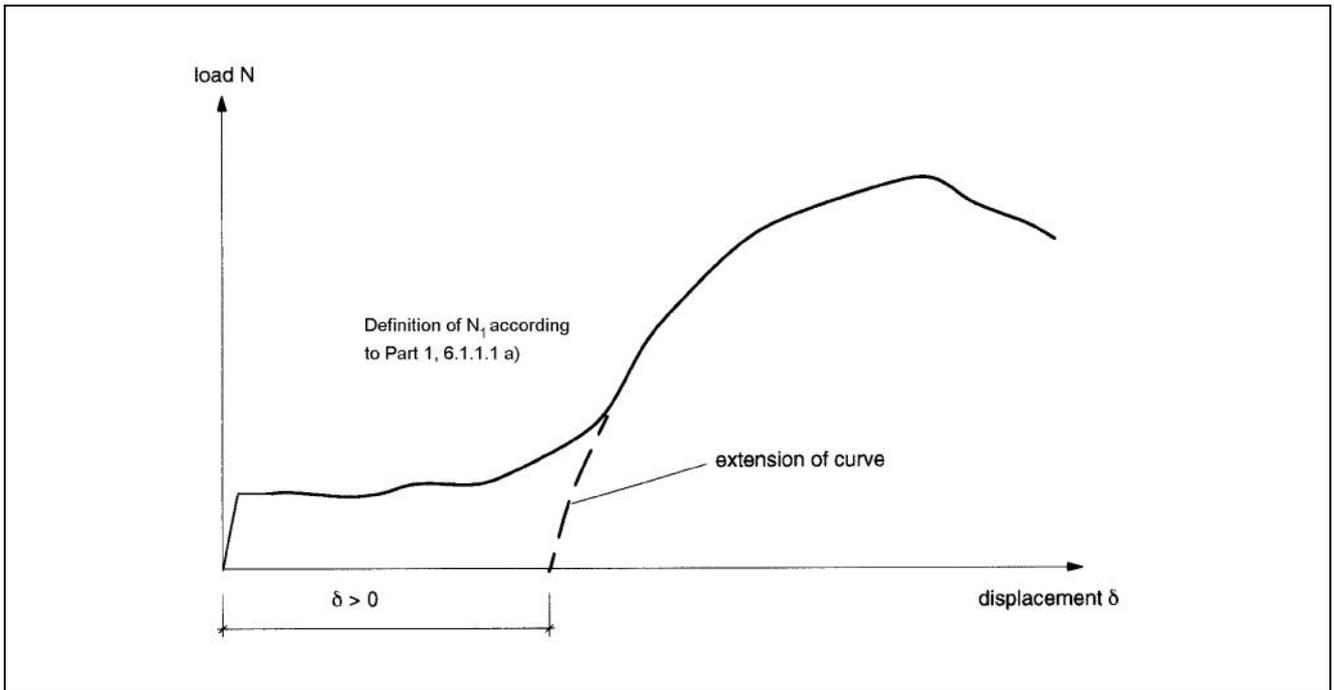


Figure 6.1.b Load/displacement behaviour with uncontrolled slip

Because it may be difficult to draw an extension to a curved line the following simplification may be used.

It is an indication of uncontrolled slip if the load/displacement curve falls below the linear connection between the peak load (ultimate load) and the zero point in any area (see Figure 6.1.c).

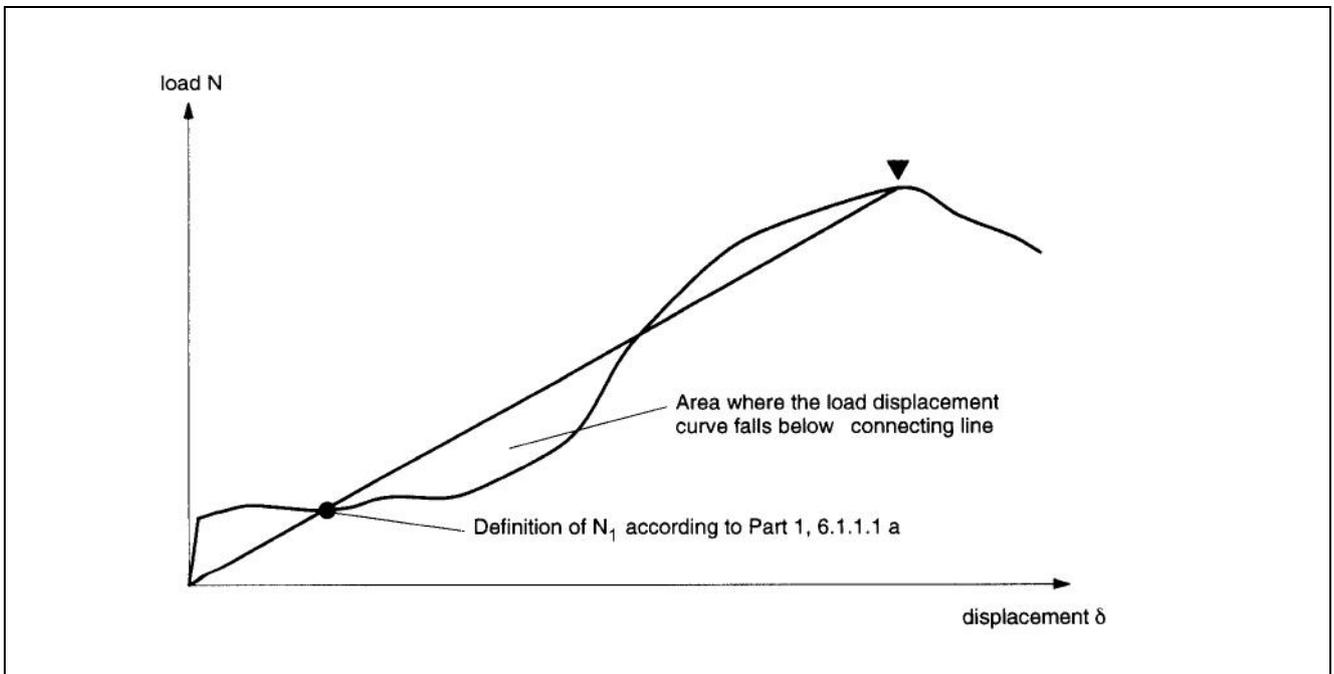


Figure 6.1.c Load/displacement behaviour with uncontrolled slip

The load N_1 according to Part 1, 6.1.1.1.a) may be defined as the lower intersection point of the straight line with the load/displacement curve.

In comparing results of assessments according to Fig. 6.1.b and 6.1.c, the type given in Fig. 6.1.b will govern.

- (c) In each test series, the coefficient of variation of the ultimate load shall be smaller than $v = 30\%$.

For a coefficient of variation of the maximum loads $15 \% \leq v \leq 30 \%$ an additional partial safety factor shall be given in the ETA.

$$\gamma_3 = 1 + [v (\%) - 15] \cdot 0,03$$

6.1.1.2 Criteria valid for specific tests

(d) Torque tests

In addition to the requirements of Part 1, 6.1.1.2(d) with anchors according to Figure 2.1(c) it shall be shown that the screw is not in contact with the cone by applying a torque moment of $T = 1,3 T_{inst}$ when using the longest screw.

6.1.2 Admissible service conditions

6.1.2.1 Criteria

- (a) In all tension tests, the requirements for the load/displacement behaviour and the failure loads shall comply with those given in Part 1, 6.1.1.1(a) and in this Part 4, 6.1.1.1(a).

7 ASSUMPTIONS UNDER WHICH THE FITNESS FOR USE IS TO BE ASSESSED

7.3 Installation of anchors

For deformation-controlled expansion anchors the suitability and the admissible service conditions are strongly influenced by the proper expansion of the sleeve.

The manufacturer's published installation specification shall give details of how the correct expansion is achieved and checked. E.g., for cone-down type anchors (drop-in anchors) a setting tool can be provided to ensure a defined expansion of the anchor. After installation, the setting tool can also be used to check the correct installation.