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GUIDELINE FOR EUROPEAN TECHNICAL APPROVAL

of

PLASTIC ANCHORS FOR MULTIPLE USE IN CONCRETE AND MASONRY FOR NON-STRUCTURAL APPLICATIONS

Part four:

PLASTIC ANCHORS FOR USE IN HOLLOW OR PERFORATED MASONRY

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FOREWORD

In this Part of ETAG "Plastic Anchors for Multiple Use in Concrete and Masonry for Non-Structural Applications" the methods of verification and the assessments required for the use of plastic anchors in hollow or perforated masonry (hollow or perforated bricks and hollow blocks to be made of clay or calcium silicate or normal weight concrete or lightweight concrete) are given. For a general assessment of plastic anchors, in principle, Part 1 applies.

Masonry units consisting of hollow or perforated units have a certain volume percentage of voids which pass through the masonry unit, compare Table 3.1 of EN 1996-1-1:2005: Eurocode 6 [8].

The required tests for suitability are given in 5.4.2 and the tests for admissible service conditions are given in Table 5.2. The determination of admissible service conditions and determination of characteristic resistances for plastic anchors to be used in hollow or perforated masonry are completely given in 6.4.3.

The same numbering of paragraphs as in Part 1 is used.

The plastic anchors for use in hollow or perforated masonry shall be used for multiple fixings. By multiple anchor use it is assumed that in the case of excessive slip or failure of one anchor the load can be transmitted to neighbouring anchors without significantly violating the requirements on the fixture in the serviceability and ultimate limit state.

Therefore the design of the fixture shall specify the number n_1 of fixing points to fasten the fixture and the number n_2 of anchors per fixing point. Furthermore the design value of actions N_{Sd} on a fixing point to a value $\leq n_3$ (kN) is specified up to which the strength and stiffness of the fixture are fulfilled and the load transfer in the case of excessive slip or failure of one anchor need not be taken into account in the design of the fixture.

The following default values for n_1, n_2 and n_3 may be taken:

$\mathbf{n_1 \geq 4}$; $\mathbf{n_2 \geq 1}$ and $\mathbf{n_3 \leq 4{,}5\ kN}$ or

$\mathbf{n_1 \geq 3}$; $\mathbf{n_2 \geq 1}$ and $\mathbf{n_3 \leq 3{,}0\ kN}$.

Section two:

GUIDANCE FOR THE ASSESSMENT OF THE FITNESS FOR USE

5. METHODS OF VERIFICATION

5.4. Safety in use

5.4.2. Tests for suitability

The types of suitability tests, test conditions, the number of required tests and the criteria applied to the results shall be taken in accordance with 5.4.2 and Table 5.1 of Part 3 (solid masonry).

For the assessment of plastic anchors to be used in hollow or perforated masonry it has also to be assumed that the anchor may be situated in solid material (e.g. joints, solid part of unit without holes) so that also tests in solid material are required.

In general plastic anchors for use in hollow or perforated masonry will be assessed for use in solid material as well. Therefore suitability tests carried out in solid material (according to Part 3, Table 5.1) or in concrete (according to Part 2, Table 5.1) are available and the results of these suitability tests ($\min\alpha_1$, $\min\alpha_2$ and $\min\alpha_V$) may be taken for the determination of the characteristic values of the plastic anchors to be used in hollow or perforated masonry.

5.4.3. Tests for admissible service conditions

The tests shall be performed in single units or in a wall. If test are done in a wall, the thickness of the joints should be about 10 mm and the joints shall be completely filled with mortar of strength class M2,5 with a strength ≤ 5 N/mm^2. If tests have been performed in walls with a mortar strength higher than M2,5 then the minimum mortar strength shall be given in the ETA. The walls may be lightly prestressed in vertical direction to allow handling and transportation of the wall.

For determination of the admissible service conditions the tests given in Table 5.2 shall be carried out.

If existing information is available from the manufacturer and the corresponding test report contains all relevant data, then the Approval Body may reduce the number of tests for admissible service conditions, making use of this existing information. However, it will be considered in the assessment only if the results are consistent with the Institute's test results or experience.

All tests for determination of admissible service conditions shall be carried out according to Annex A in the base material for which the plastic anchor is intended to be used at normal ambient temperature (+21°C $\pm$ 3°C) and standard conditioning of the polymeric sleeve. The drill holes shall be drilled using $d_{cut,m}$ drill bits.

The minimum edge distance c_{min} and minimum spacing s_{min} shall be given by the manufacturer and shall be confirmed by the tests according to Table 5.2, line 2.

The determined characteristic resistances for the ETA are valid for the bricks and blocks only which are used in the tests regarding base material, size of units, compressive strength and configuration of the voids. Therefore the following information has to be given in the test report and in the ETA:

Base material, size of units, normalised compressive strength; volume of all holes (% of the gross volume); volume of any hole (% of the gross volume); minimum thickness in and around holes (web and shell); combined thickness of webs and shells (% of the overall width); appropriation to a group of Table 3.1 of EN 1996-1-1:2005: Eurocode 6 [8].

Table 5.2: Tests for admissible service conditions for plastic anchors for use in hollow or perforated masonry

	1	2	3	4	5	6	7
	Purpose of test	**Load direc tion**	**Distances**	**Member thickness h**	**Remarks**	**Minimum Number of tests for s, m, l (4)**	**Test procedure described in Annex A**
1	Characteristic resistance for tension loading not influenced by edge and spacing effects	N	$s > s_{min}$ $c > c_{min}$	$\geq h_{min}$	test with single anchor **(1)**	5	Annex A, 5.2
2	Minimum edge distance for characteristic tension resistance	N	$s > s_{min}$ **(3)** $c = c_{min}$	$= h_{min}$	test with single anchor **(2)**	5	Annex A, 5.2
3	Minimum edge distance for shear loading	V	$s > s_{min}$ $c = c_{min}$	$= h_{min}$	test with single anchor **(5)**	5	Annex A, 5.4

(1) The tests shall be carried out at the most unfavourable setting position in the brick, which give the lowest characteristic resistance of the anchor

(2) Tension tests with a single anchor near the free edge of a wall to determine the characteristic resistance depending on the minimum edge distance c_{min}

(3) Tension tests with double anchor group with $s = s_{min}$ near the free edge ($c = c_{min}$) to determine the characteristic resistance for the minimum spacing s_{min} and the minimum edge distance c_{min} are required if the chosen minimum spacing is lower than the following values:

$s_{min} < 4 \cdot c_{min}$ (groups with spacing parallel to the edge)

$s_{min} < 2 \cdot c_{min}$ (groups with spacing perpendicular to the edge)

If there is a wide range of hollow or perforated masonry units to be stated in the ETA [e.g. 2 or more different hollow clay bricks/hollow sand-lime bricks/lightweight concrete hollow blocks - different in respect of compressive strength, brick size and/or volume percentage of voids which pass through the masonry unit (compare Part 1, 2.1.3.4)], tension tests with the double anchor group have only to be performed for the most unfavourable hollow clay bricks/hollow sand-lime bricks/lightweight concrete hollow blocks.

Example: There are 2 hollow sand-lime bricks only different with respect to the outer web thickness, e.g. 12 mm (brick 1) and 20 mm (brick 2), and the plastic anchor may only be embedded in the outer shell. In this case tension tests with the double anchor group have to be performed only with brick 1, since according to experience this brick will bring the lowest characteristic resistance for the plastic anchor.

(4) Anchor sizes small (s), medium (m) and large (l) of an anchor system shall be tested; intermediate sizes need not to be tested

(5) Shear tests towards the edge are required only if the edge distance to the edge of the wall is smaller than 100 mm or F_{Rk} is greater than 2,5 kN or the expansion element is made of polymeric material.

Shear tests towards the edge are also required if anchors are to be used under shear load with lever arm (without bearing on the base material) and/or if the anchor is only embedded in the outer shell of the hollow or perforated masonry. These additional shear tests are needed to check the suitability for this type of installation.

In general the tests shall be carried out with the minimum overall anchor embedment depth min h_{nom} given by the manufacturer. These test results are valid for the minimum overall anchor embedment depth min h_{nom} only because the performance of the anchor with larger overall anchor embedment depth than min h_{nom} can be reduced depending on the volume of holes (see Figure 5.1). If the manufacturer provides a wide range of thickness of fixture t_{fix} for the individual anchor then the possible larger embedment depths (larger embedment depth if t_{fix} is smaller than max t_{fix}) shall be tested or the performance of the anchor shall be determined by job site tests according to Annex B.

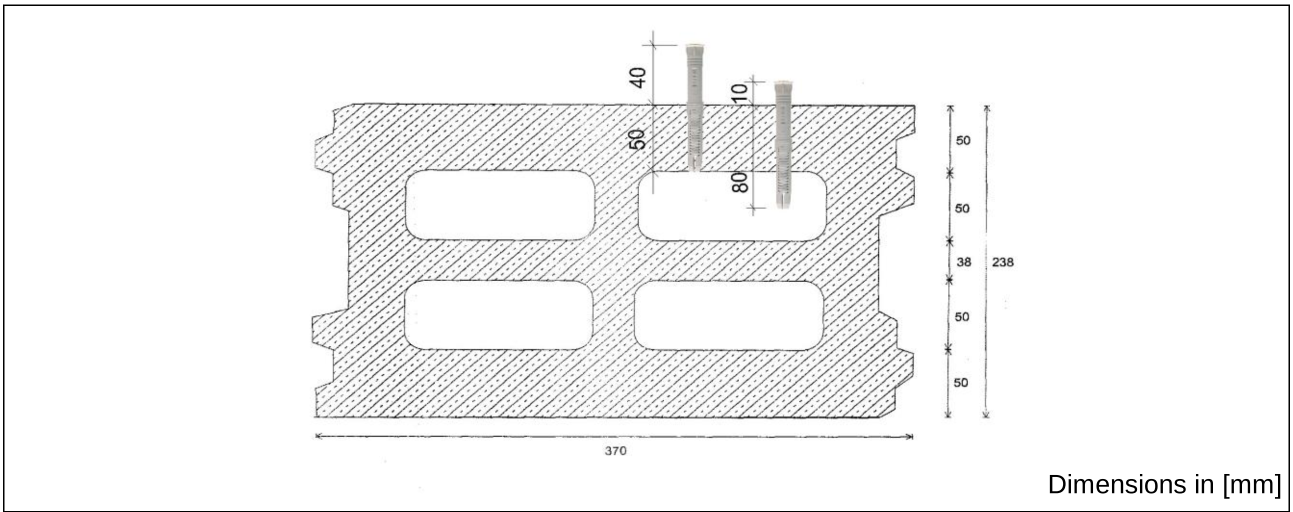

Figure 5.1: Example of plastic anchor with a total length of 90 mm designed for a maximum thickness of fixture of 40 mm (max t_{fix} = 40 mm) in different setting positions

6. ASSESSING AND JUDGING THE FITNESS FOR AN USE

6.4. Safety in use

6.4.1.2. Conversion of ultimate loads to take account of concrete-, masonry- and steel strength

In contrast to Equation (6.0b) the conversion of the test results in hollow or perforated masonry shall be carried out according to 6.4.3.2.

6.4.1.3. Criteria for all tests

In all tests the following criteria shall be met:

(2) In general, in each test series, the coefficient of variation of the ultimate load shall be smaller than v = 20 % in the **suitability tests** and v = 15 % in the **admissible service condition tests**.

If the coefficient of variation of the ultimate load in the **suitability test** is greater than 20 %, then the following α_V-value has to be taken into account:

$$\alpha_V = \frac{1}{1+0{,}03(v[\%]-20)} \leq 1{,}0 \qquad \textbf{(6.6a)}$$

If the coefficient of variation of the ultimate load in the **admissible service condition test** is greater than 15 %, then the following α_V-value has to be taken into account:

$$\alpha_V = \frac{1}{1+0{,}03(v[\%]-15)} \leq 1{,}0 \qquad \textbf{(6.6b)}$$

6.4.2. Criteria valid for suitability tests

In the suitability tests the criteria described in Part 1, 6.4 shall be met. The values of the reference tests are taken from the tests according to Table 5.2, line 1.

If there are existing tests for suitability carried out in solid masonry (according to Part 3, Table 5.1) or in concrete (according to Part 2, Table 5.1) for the plastic anchors, then the results of these suitability tests (minα_1, minα_2 and minα_V) may be taken for the determination of the characteristic values of the plastic anchors to be used in hollow or perforated masonry.

6.4.3. Admissible service conditions

6.4.3.1. General

In all tension tests the requirement for the load/displacement curves shall satisfy the requirements laid down in Part 1, 6.4.1.3 (1). The requirements on the coefficient of variation of the ultimate loads are given in 6.4.1.3 (2) and Equation (6.6b).

6.4.3.2. Characteristic resistance of single anchor for the different conditions

(1) Tension loading not influenced by edge and spacing effects (Table 5.2, line 1)

The characteristic resistances of single anchors without edge and spacing effects under tension loading shall be calculated as follows:

$$\mathbf{N_{Rk} = N_{Rk1,0} \cdot min^{1)} (min\ \alpha_1 ; min\ \alpha_{2,\ line\ 1,2,6,7}) \cdot min\ \alpha_{2,\ line\ 4,5} \cdot min\ \alpha_V} \quad \mathbf{(6.7)}$$

[1] *The lowest value of min α_1 or min $\alpha_{2,\ \text{line 1,2,6,7}}$ is governing.*

with:

$N_{Rk1,0}$ = characteristic resistance evaluated from the results of tests according to Table 5.2, line 1

In the absence of better information the influence of the unit compressive strength has to be considered with the ratio $f_b/f_{b,test}$ according to Equation (6.8).

min α_1 = minimum value α_1 (reduction factor from the load/displacement behaviour) according to Part 1, Equation (6.2) of all tests

≤ **1,0**

min $\alpha_{2,line\ 4,5}$ = minimum value α_2 (reduction factor from the ultimate loads in the suitability tests) according to Part 1, Equation (6.5) of suitability tests according to Table 5.1, line 4 and 5 (conditioning and temperature)

≤ **1,0**

min $\alpha_{2,\ line\ 1,2,,6,7}$ = minimum value α_2 (reduction factor from the ultimate loads in the suitability tests) according to Part 1, Equation (6.5) of suitability tests according to Table 5.1, line 1, 2, 6 and 7

≤ **1,0**

min α_V = minimum value α_V to consider a coefficient of variation of the ultimate loads in the suitability and admissible service condition tests larger than 20% and 15%, respectively; see Equations (6.6a) and (6.6b).

(2) Tension loading influenced by minimum edge effects (Table 5.2, line 2)

The characteristic resistances of single anchors near the free edge under tension loading shall be calculated as follows:

$$\mathbf{N_{Rk2} = N_{Rk2}^{t} \cdot \frac{f_b}{f_{b,test}} \cdot \min \alpha_1 \cdot \min \alpha_V}\ ^{1)} \qquad \textbf{(6.8)}$$

[1] If pull-out failure is observed in tests according to Table 5.2, line 2, then the evaluation shall be done according to Equation (6.7).

with:

N_{Rk2}^{t}	=	characteristic resistance evaluated from the results of tests according to Table 5.2, line 2
f_b	=	normalised mean compressive strength of the chosen masonry unit in the ETA
$f_{b,test}$	=	mean compressive strength of the test masonry unit
$\min \alpha_1$	=	minimum value α_1 (reduction factor from the load/displacement behaviour) according to Part 1, Equation (6.2) of all tests
	$\leq$	1,0
$\min \alpha_V$	=	minimum value α_V to consider a coefficient of variation of the ultimate loads in the suitability and admissible service condition tests larger than 20 % and 15 %, respectively; see Equations (6.6a) and (6.6b).

(3) Tension loading influenced by minimum spacing effects (Table 5.2, footnote (3))

In the design concept it is assumed that a group with 2 or 4 anchors with $s \geq s_{min}$ has the same characteristic resistance as a single anchor with a large spacing to neighbouring anchors. Therefore the characteristic resistances of single anchors N_{Rk3} with minimum spacing near the free edge under tension loading shall be calculated according to 6.4.3.2 (2), however as value N_{Rk2}^{t} the characteristic resistance evaluated from the results of tests according to Table 5.2, footnote (3) shall be taken.

If pull-out failure is observed in tests according to Table 5.2, footnote (3), then the evaluation shall be done according to Equation (6.7).

(4) Shear loading

If shear tests towards the edge are performed and brick edge failure occurs the characteristic shear resistance shall be calculated as follows:

$$\mathbf{V_{Rk,b} = V_{Ru}^{t} \cdot \frac{f_b}{f_{b,test}} \cdot \min \alpha_V} \qquad \textbf{(6.9)}$$

with:

V_{Ru}^{t} = characteristic resistance evaluated from the results of tests

f_b = normalised mean compressive strength of the chosen masonry unit in the ETA

$f_{b,test}$ = mean compressive strength of the test masonry unit

min α_V = minimum value α_V to consider a coefficient of variation of the ultimate loads in the suitability and admissible service condition tests larger than 20 % and 15 %, respectively; see Equations (6.6a) and (6.6b).

If the edge of the wall c_{min} is greater than 100 mm or F_{Rk} is smaller than 2,5 kN no shear tests are required and the characteristic shear resistances $V_{Rk,s}$ of the metal expansion element for single anchors may be calculated as follows:

$$\mathbf{V_{Rk,s} = 0{,}5 \cdot A_s \cdot f_{uk}} \qquad \textbf{(6.10)}$$

with:

A_s = stressed cross section of steel

f_{uk} = characteristic steel ultimate tensile strength (nominal value)

6.4.3.3. Characteristic resistance of single anchor in the ETA

For the determination of the characteristic resistance $\mathbf{F_{Rk}}$ the design values for N_{Rk1}, N_{Rk2}, N_{Rk3}, $V_{Rk,b}$ and $V_{Rk,s}$ have to be calculated under consideration of the appropriated partial safety factors. The corresponding partial safety factors are given in 7.1.2.

The minimum design value is decisive for the characteristic resistance $\mathbf{F_{Rk}}$ given in the ETA.

The value of the characteristic resistance $\mathbf{F_{Rk}}$ shall be rounded to the following numbers:

F_{Rk} = 0,3 / 0,4 / 0,5 / 0,6 / 0,75 / 0,9 / 1,2 / 1,5 / 2 / 2,5 / 3 / 3,5 / 4 / 4,5 / 5 / 5,5 / 6 / 6,5 / 7 / 7,5 / 8 / 8,5 / 9 / 9,5 / 10 / 10,5 / 11 / 11,5 / … kN

$\leq \mathbf{N_{Sd} \cdot \gamma_{Mm}}$

6.4.3.4. Displacement behaviour

As a minimum, the displacements under short and long term tension and shear loading shall be given in the ETA for a load F which corresponds approximately to the value according to Equation (6.11)

$$F = \frac{F_{Rk}}{\gamma_F \cdot \gamma_M} \qquad \textbf{(6.11)}$$

with:

F_{Rk} = characteristic resistance according to 6.4.3.3

γ_F = 1,4

γ_M = corresponding material partial safety factor

The displacements under short term tension loading (δ_{NO}) are evaluated from the tests with single anchors without edge or spacing effects according to Table 5.2, line 1. The value derived shall correspond approximately to the 95 %-fractile for a confidence level of 90 %.

The long term tension loading displacements $\delta_{N\infty}$ may be assumed to be approximately equal to 2,0-times the value δ_{NO}.

The displacements under short term shear loading (δ_{VO}) are evaluated from the corresponding shear tests with single anchors. The value derived shall correspond approximately to the 95 %-fractile for a confidence level of 90 %.

If no shear tests are performed the displacements under short term shear loading (δ_{VO}) for a plastic anchor with metal expansion element may be determined for the load according to Equation (6.11) with a shear stiffness of 1200 N/mm.

The long term shear loading displacements $\delta_{V\infty}$ may be assumed to be approximately equal to 1,5-times the value δ_{VO}.

Under shear loading the displacements might increase due to a gap between fixture and anchor. The influence of this gap shall be taken into account in the design.

7. ASSUMPTIONS AND RECOMMENDATIONS UNDER WHICH THE FITNESS FOR USE OF THE PRODUCTS IS ASSESSED

7.1. Design methods for anchorage in hollow or perforated masonry

7.1.1. Multiple use

The plastic anchors for use in hollow or perforated masonry shall be used for multiple fixings. By multiple anchor use it is assumed that in the case of excessive slip or failure of one anchor the load can be transmitted to neighbouring anchors without significantly violating the requirements on the fixture in the serviceability and ultimate limit state.

Therefore the design of the fixture shall specify the number n_1 of fixing points to fasten the fixture and the number n_2 of anchors per fixing point. Furthermore the design value of actions N_{Sd} on a fixing point to a value $\leq n_3$ (kN) is specified up to which the strength and stiffness of the fixture are fulfilled and the load transfer in the case of excessive slip or failure of one anchor need not be taken into account in the design of the fixture.

The following default values for n_1, n_2 and n_3 may be taken:

$\mathbf{n_1 \geq 4}$; $\mathbf{n_2 \geq 1}$ and $\mathbf{n_3 \leq 4{,}5\ kN}$ or

$\mathbf{n_1 \geq 3}$; $\mathbf{n_2 \geq 1}$ and $\mathbf{n_3 \leq 3{,}0\ kN}$.

7.1.2. Design and safety concept

The design concept with partial safety factors shall be used for anchorages in solid masonry.

In the absence of national regulations the following partial safety factors for resistances γ_M may be used:

Steel failure:

- Tension loading:

$$\gamma_{Ms} = \frac{1,2}{f_{yk} / f_{uk}} \geq 1,4 \qquad (7.1)$$

- Shear loading of the anchor with and without lever arm:

$$\gamma_{Ms} = \frac{1,0}{f_{yk} / f_{uk}} \geq 1,25 \qquad f_{uk} \leq 800\ N/mm^2 \quad \text{and} \quad f_{yk} / f_{uk} \leq 0,8 \qquad (7.2)$$

$$\gamma_{Ms} = 1,5 \qquad f_{uk} > 800\ N/mm^2 \quad \text{or} \quad f_{yk} / f_{uk} > 0,8 \qquad (7.3)$$

Other failure modes:

$$\gamma_{Mm} = 2,5 \qquad (7.4)$$

7.1.3 Specific conditions for the design method in masonry

(1) The ETA shall contain only one characteristic resistance $\mathbf{F_{Rk}}$ independent of the load direction and the mode of failure. The appropriated partial safety factor and the corresponding values c_{min} and s_{min} for this characteristic resistance shall also be given.

(2) The characteristic resistance $\mathbf{F_{Rk}}$ for a single plastic anchor shall also be taken for a group of two or four plastic anchors with a spacing equal or larger than the minimum spacing s_{min}.

The distance between single plastic anchors or a group of anchors is $a \geq 250$mm.

(3) See also Annex C, 5.3 (3).

Section four:
ETA CONTENT

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9. THE ETA CONTENT

9.1.4. Characteristics of the anchor with regard to safety in use and methods of verification

- Characteristic values to be used for the calculation of the ultimate limit state:

The ETA shall contain only one characteristic resistance $\mathbf{F_{Rk}}$ for one base material independent of the load direction and the mode of failure. The appropriated partial safety factor and the corresponding values c_{min} and s_{min} for this characteristic resistance shall also be given in the ETA.

The determined characteristic resistances for the ETA are valid for the bricks and blocks only which are used in the tests regarding base material, size of units, compressive strength and configuration of the voids. Therefore the following information has to be given in the test report and in the ETA:

Base material, size of units, normalised compressive strength; volume of all holes (% of the gross volume); volume of any hole (% of the gross volume); minimum thickness in and around holes (web and shell); combined thickness of webs and shells (% of the overall width); appropriation to a group of Table 3.1 of EN 1996-1-1:2005: Eurocode 6 [8].

If tests have been performed in walls with a mortar strength higher than M2,5 then the minimum mortar strength shall be given in the ETA.

The characteristic resistance of the plastic anchor may be determined by "job site tests" according to Annex B, if the plastic anchor has an ETA with characteristic values for the same base material as it is present on the construction works. Furthermore job site tests for use in solid masonry are possible only if the plastic anchor has an ETA for use in solid masonry and job site tests for use in hollow or perforated masonry are possible only if the plastic anchor has an ETA for use in hollow or perforated masonry

The characteristic resistances are valid for the minimum overall anchor embedment depth min h_{nom} only because the performance of the anchor with larger embedment depth than min h_{nom} may be reduced depending on the volume of holes. If the manufacturer provides a wide range of thickness of fixture t_{fix} for the individual anchor then the possible different characteristic resistances for larger embedment should be given in the ETA or this performance of the anchor should be determined by job site tests according to Annex B.

9.1.6. Assumptions under which the fitness of the anchor for the intended use was favourably assessed

The specific conditions (2) and (3) for the design method according to 7.1.3 shall be given in the ETA as well.