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**GUIDELINE FOR EUROPEAN TECHNICAL APPROVAL
of
METAL INJECTION ANCHORS FOR USE IN MASONRY**

Annex C : DESIGN METHODS FOR ANCHORAGES

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Introduction

The design method for anchorages is intended to be used for the design of anchorages under due consideration of the safety and design concept within the scope of the European Technical Approvals of injection anchors for use in masonry.

The design method given in Annex C is based on the assumption that the required tests for assessing the admissible service conditions given in this Guideline have been carried out. The use of other design methods will require reconsideration of the necessary tests.

C.1 Scope

C.1.1 Type of anchors, anchor groups and number of anchors

The design method applies to the design of injection anchors in masonry units of clay, calcium silicate, normal weight concrete, autoclaved aerated concrete (AAC) or other similar materials using anchors which fulfil the requirements of this Guideline. The characteristic values are given in the relevant approval.

The design method is valid for single anchors and anchor groups with two or four anchors. In an anchor group only anchors of the same type, size and length shall be used.

C.1.2 Member

C.1.2.1 Solid and hollow or perforated masonry

The masonry member shall be of solid or hollow or perforated masonry units made of clay or calcium silicate or normal weight concrete.

The detailed information of the corresponding base material is given in the approval (e.g. *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).*

C.1.2.2 Autoclaved aerated concrete

The autoclaved aerated concrete member shall be according to EN 771-4:2003 + A1:2005 [2] "Autoclaved aerated concrete masonry units" or EN 12 602 [3] "Reinforced components of autoclaved aerated concrete".

C.1.3 Type and direction of load

This design method applies to injection anchors subject to static or quasi-static actions in tension, shear or combined tension and shear or bending; it is not applicable to injection anchors loaded in compression or subject to fatigue, impact, or seismic actions.

C.2 Terminology and symbols

The explanations of the notations and symbols are given in the general part of the ETAG.

C.3 Design and safety concept

C.3.1 General

The design of anchorages shall be in accordance with the general rules given in EN 1990 [11]. It shall be shown that the value of the design actions S_d does not exceed the value of the design resistance R_d .

$$S_d \leq R_d \quad (C.3.1)$$

$$\begin{aligned} S_d &= \text{value of design action} \\ R_d &= \text{value of design resistance} \end{aligned}$$

Actions to be used in design may be obtained from national regulations or in the absence of them from the relevant parts of EN 1991:2002 [12].

The partial safety factors for actions may be taken from national regulations or in the absence of them according to EN 1990:2002 [11].

The design **resistance** is calculated as follows:

$$R_d = R_k / \gamma_M \quad (C.3.2)$$

$$\begin{aligned} R_k &= \text{characteristic resistance of a single anchor or an anchor group} \\ \gamma_M &= \text{partial safety factor for material} \end{aligned}$$

C.3.2 Ultimate limit state

C.3.2.1 Design resistance

The design resistance is calculated according to Equation (C.3.2).

C.3.2.2 Partial safety factors for resistances

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

3.2.2.1 Failure (rupture) of the metal part

Tension loading:

$$\gamma_{Ms} = \frac{1.2}{f_{yk} / f_{uk}} \geq 1.4 \quad (C.3.3a)$$

Shear loading of the anchor with and without lever arm:

$$\gamma_{Ms} = \frac{1.0}{f_{yk} / f_{uk}} \geq 1.25 \quad f_{uk} \leq 800 \text{ N/mm}^2 \quad (C.3.3b)$$

$$\text{and } f_{yk} / f_{uk} \leq 0.8$$

$$\gamma_{Ms} = 1.5 \quad \text{or } \begin{aligned} &f_{uk} > 800 \text{ N/mm}^2 \\ &f_{yk} / f_{uk} > 0.8 \end{aligned}$$

3.2.2.2 Failure of the injection anchor

a) *For use in masonry*

$$\gamma_{Mm} = 2.5$$

b) *For use in autoclaved aerated concrete*

$$\gamma_{MAAC} = 2.0$$

C.3.3 Serviceability limit state

In the serviceability limit state it shall be shown that the displacements occurring under the characteristic actions (see C.6) are not larger than the permissible displacements. The permissible displacements depend on the application in question and shall be evaluated by the designer.

In this check the partial safety factors on actions and on resistances may be assumed to be equal 1.0.

C.4 Static analysis

C.4.1 Loads acting on anchors

Distribution of loads acting on anchors shall be calculated according to the theory of elasticity.

For steel failure under tension and shear and for pull-out failure under tension the load acting on the highest loaded anchor shall be determined.

In case of brick edge failure the shear force is assumed to act on the anchor(s) closest to the edge.

C.4.2 Shear loads with or without lever arm

Shear loads acting on an anchor may be assumed to act without lever arm if all of the following conditions are fulfilled:

1. The fixture shall be made of metal and in the area of the anchorage be fixed directly to the base material without an intermediate layer or with a levelling layer of mortar with a compressive strength $\geq 30\text{N/mm}^2$ and a thickness $\leq d/2$.
2. The fixture is in contact with the anchor over a length of at least $0.5 \cdot t_{\text{fix}}$.
3. The diameter d_f of the hole in the fixture is not greater than the values d_f given in Table C.4.1.

If these two conditions are not fulfilled the lever arm is calculated according to Equation (C.4.1) (see Fig. C.4.1).

$$l = a_3 + e_1 \quad (\text{C.4.1})$$

e_1 = distance between shear load and surface of the member

a_3 = $0.5 \cdot d$

d = nominal diameter of the anchor

Table C.4.1 Diameter of clearance hole in the fixture

external diameter d or d_{nom} (mm)	6	8	10	12	14	16	18	20	22	24	30
diameter of clearance hole in the fixture d_f (mm)	7	9	12	14	16	18	20	22	24	26	33

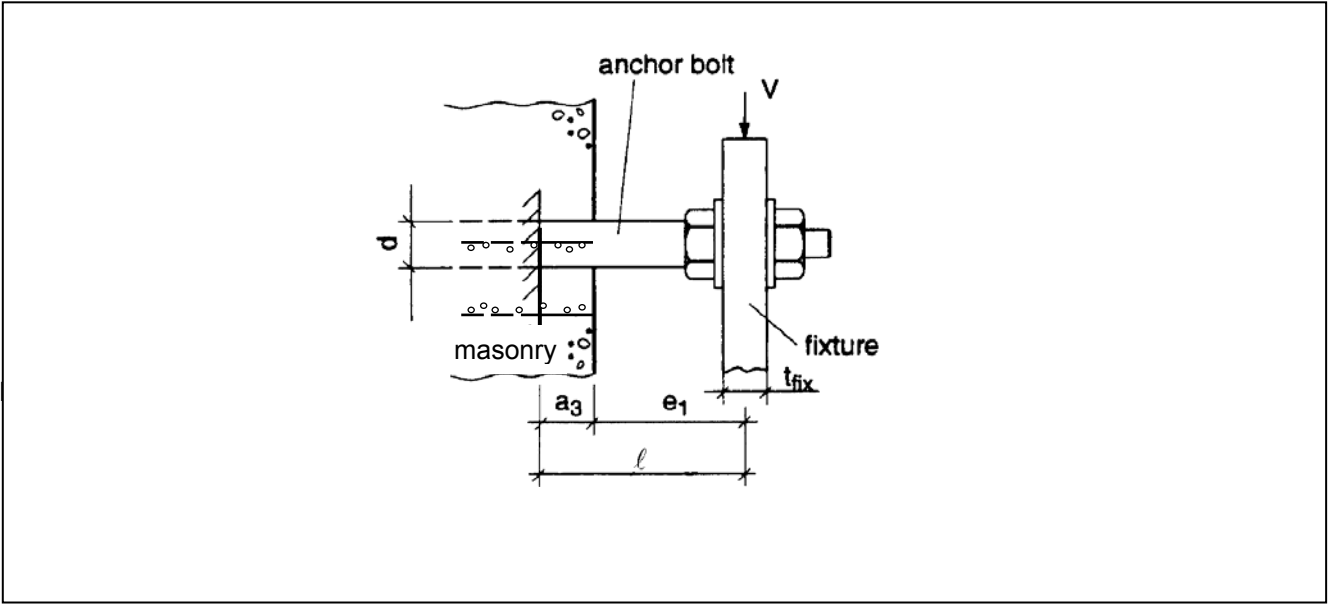


Figure C.4.1 Definition of lever arm

C.5. Ultimate limit state

C.5.1 General

For the design of anchorages in the ultimate limit state, there are two different design methods available. The general design method A is described in C.5.2 and a simplified design method B is given in C.5.3.

Spacing, edge distance as well as thickness of member shall not remain under the given minimum values in the approval.

C.5.2 Design method A for use in masonry

In design method A it shall be shown that Equation (C.3.1) is observed for all loading directions (tension, shear) as well as all failure modes (steel failure, pull-out failure and brick failure).

In case of a combined tension and shear loading (oblique loading) the condition of interaction according to C.5.2.3 shall be observed.

C.5.2.1 Resistance to tension loads

C.5.2.1.1 Required proofs

Failure of the metal part	$N_{Sd}^h \leq N_{Rk,s} / \gamma_{Ms}$	C.5.2.1.2
Pull-out failure of the anchor	$N_{Sd}^h \leq N_{Rk,p} / \gamma_{Mm}$	C.5.2.1.3
Brick breakout failure	$N_{Sd} \leq N_{Rk,b} / \gamma_{Mm}$ $N_{Sd}^g \leq N_{Rk,b}^g / \gamma_{Mm}$	C.5.2.1.4
Pull out of one brick	$N_{Sd} \leq N_{Rk,pb} / \gamma_{Mm}$	C.5.2.1.5
Influence of joints	$N_{Sd} \leq \alpha_j N_{Rk,p} / \gamma_{Mm}$ $N_{Sd} \leq \alpha_j N_{Rk,b} / \gamma_{Mm}$	C.5.2.1.6

for anchorages in AAC the partial safety factor γ_{MAAC} is to be used instead of γ_{Mm}

C.5.2.1.2 Failure of the metal part

The characteristic resistance of an anchor in case of failure of the metal part, $N_{Rk,s}$, is given in the relevant approval.

The value of $N_{Rk,s}$ is obtained from Equation (C.5.1)

$$N_{Rk,s} = A_s \cdot f_{uk} \text{ [N]} \quad (C.5.1)$$

C.5.2.1.3 Pull-out failure of the anchor

The characteristic resistance in case of failure by pull-out of the anchor, $N_{Rk,p}$, shall be taken from the relevant approval.

C.5.2.1.4 Brick breakout failure

The characteristic resistance of one anchor in case of brick breakout failure, $N_{Rk,b}$, is given in the relevant approval.

The characteristic resistance of a group of two injection anchors, $N_{Rk,b}^g$ may be calculated by the following Equation:

$$N_{Rk,b}^g = N_{Rk,b} \cdot \left(1 + \frac{s}{s_{cr,N}} \right) \leq 2 N_{Rk,b} \quad (C.5.2)$$

with:

- $N_{Rk,b}^g$ = characteristic resistance of the whole group of two injection anchors
- s = available spacing of the injection anchors
- $s_{cr,N}$ = spacing for ensuring the transmission of characteristic resistance of one anchor given in the approval; the spacing is determined as follows:
 - for anchorages in solid masonry and AAC: $s_{cr,N} = 20d$
 - for anchorages in hollow or perforated masonry: $s_{cr,N} = l_{unit}$
 - for anchorages in all types of masonry: $s_{cr,N} = s_{cr,test}$
- l_{unit} = given in the approval (length of masonry unit in the tests)
- $s_{cr,test}$ = given in the approval (spacing of a group of anchors in the tests)

The above determination is possible only if the wall is designed such that the joints are to be filled with mortar so that load transfer to other units in the wall is given.

If there are spacings in two directions (quadruple anchor group) then the above influence factor may be determined for each directions and shall be multiplied in Equation (C.5.2).

The available spacing s shall not remain under the given minimum values in the approval.

The minimum distances according to current experience are given below:

$$s_{min} = c_{min} = \geq 50mm \geq 3 d_o \quad \text{for solid material}$$

$$s_{min} = c_{min} = \geq 100mm \geq 6 d_o \quad \text{for hollow material}$$

C.5.2.1.5 Pull out of one brick

The characteristic resistance of an anchor or a group of anchors in case of pull out of one brick, $N_{Rk,pb}$, is calculated as follows:

Vertical joints are designed not to be filled with mortar

$$N_{Rk,pb} = 2 \cdot l_{brick} \cdot b_{brick} (0.5 \cdot f_{vko} + 0.4 \cdot \sigma_d) \quad (C.5.3)$$

Vertical joints are designed to be filled with mortar

$$N_{Rk,pb} = 2 \cdot l_{brick} \cdot b_{brick} (0.5 \cdot f_{vko} + 0.4 \cdot \sigma_d) + b_{brick} \cdot h_{brick} \cdot f_{vko} \quad (C.5.4)$$

- $N_{Rk,pb}$ = characteristic resistance for pull out of one brick
- l_{brick} = length of the brick
- b_{brick} = breadth of the brick
- h_{brick} = height of the brick
- σ_d = design compressive stress perpendicular to the shear
- f_{vko} = initial shear strength according to EN 1996-1-1:2005, Table 3.4

Brick type	mortar strength	f_{vko} [N/mm ²]
clay brick	M2,5 to M9	0.2
	M10 to M20	0.3
all other types	M2,5 to M9	0.15
	M10 to M20	0.2

C.5.2.1.6 Influence of joints

If the joints of the masonry are not visible the characteristic resistances $N_{Rk,p}$ and $N_{Rk,b}$ have to be reduced by the factor $\alpha_j = 0.75$.

If the joints of the masonry are visible (e.g. unplastered wall), the following has to be taken into account:

- The characteristic resistance $N_{Rk,p}$ and $N_{Rk,b}$ may be used only if the wall is designed such that the joints are to be filled with mortar.
- If the wall is designed such that the joints are not to be filled with mortar then the characteristic resistance $N_{Rk,p}$ and $N_{Rk,b}$ may be used only if the minimum edge distance c_{min} to the vertical joints is observed. If this minimum edge distance c_{min} can not be observed then the characteristic resistance $N_{Rk,p}$ and $N_{Rk,b}$ has to be reduced by the factor $\alpha_j = 0.75$.

C.5.2.2 Resistance to shear loads

C.5.2.2.1 Required proofs

Failure of the metal part, shear load without lever arm	$V_{Sd}^h \leq V_{Rk,s} / \gamma_{Ms}$	C.5.2.2.2
Failure of the metal part, shear load with lever arm	$V_{Sd}^h \leq V_{Rk,s} / \gamma_{Ms}$	C.5.2.2.3
Local brick failure	$V_{Sd} \leq V_{Rk,b} / \gamma_{Mm}$	C.5.2.2.4
Brick edge failure	$V_{Sd} \leq V_{Rk,c} / \gamma_{Mm}$	C.5.2.2.5

for anchorages in AAC the partial safety factor γ_{MAAC} is to be used instead of γ_{Mm}

C.5.2.2.2 Failure of the metal part, shear load without lever arm

The characteristic resistance of an anchor in case of failure of the metal part due to shear load without lever arm $V_{Rk,s}$ shall be taken from the relevant approval.

The value of $V_{Rk,s}$ is obtained from Equation (C.5.5)

$$V_{Rk,s} = 0.5 \cdot A_s \cdot f_{uk} [N] \quad (5.5)$$

C.5.2.2.3 Failure of the metal part, shear load with lever arm

The characteristic resistance of an anchor in case of failure of the metal part due to shear load with lever arm $V_{Rk,s}$ is given by Equation (5.6).

$$V_{Rk,s} = \frac{M_{Rk,s}}{\ell} [N] \quad (5.6)$$

ℓ lever arm according to Equation (C.4.1)
 $M_{Rk,s}$ to be taken from the relevant approval

C.5.2.2.4 Local brick failure

The characteristic resistance of an anchor in case of local brick failure, $V_{Rk,b}$, is given in the relevant approval.

C.5.2.2.5 Brick edge failure

The characteristic resistance for an anchor in the case of brick edge failure with a defined edges $V_{Rk,c}$, is given in the relevant ETA.

For anchorages in solid masonry and AAC the following determination may be used:

$$V_{Rk,c} = 0.45^{1)} \cdot \sqrt{d_{nom}} \cdot (h_{nom} / d_{nom})^{0.2} \cdot \sqrt{f_b} \cdot c_1^{1.5} \quad [N] \quad (C.5.7)$$

¹⁾ factor 0.25 instead of 0.45 if the load direction is to the free edge

$d_{nom}, h_{nom}, h, c_1, c_2$ [mm]; f_b [N/mm²]
 c_1 edge distance closest to the edge in loading direction

For anchorages in hollow or perforated masonry the following values correspond to current experience and no further determination required :

$$V_{Rk,c} \leq 2.5 \text{ kN} \quad \text{with } c_{min} \geq 100 \text{ mm}$$

C.5.2.3 Resistance to combined tension and shear loads

For combined tension and shear loads the following Equations shall be satisfied:

$$\beta_N \leq 1 \quad (C.5.8a)$$

$$\beta_V \leq 1 \quad (C.5.8b)$$

$$\beta_N + \beta_V \leq 1.2 \quad (C.5.8c)$$

β_N (β_V) ratio between design action and design resistance for tension (shear) loading.

In Equation (C.5.8) the largest value of β_N and β_V for the different failure modes shall be taken (see C.5.2.1.1 and C.5.2.2.1).

C.5.3 Design method B for use in masonry

Design method B is based on a simplified approach in which only one value for the design resistance F_{Rd} is given, independent of loading direction and mode of failure. The design resistance F_{Rd} is calculated by the lowest value under consideration of the characteristic resistances and the corresponding partial safety factors. The actual spacing and edge distance shall be equal to or larger than the values of s_{cr} and c_{cr} . F_{Rd} , s_{cr} and c_{cr} are given in the relevant approval.

In case of shear load with lever arm the characteristic anchor resistance shall be calculated according to Equation (C.5.6).

The characteristic resistance of an anchor or a group of anchors in case of pull-out of one brick and the influence of joints shall be considered according to C.5.2.1.5 and C.5.2.1.6 in every application.

C.6 Serviceability limit state

C.6.1 Displacements

The characteristic displacement of the anchor under defined tension and shear loads shall be taken from the approval. It may be assumed that the displacements are a linear function of the applied load. In case of a combined tension and shear load, the displacements for the tension and shear component of the resultant load shall be geometrically added.

In case of shear loads the influence of the hole clearance in the fixture on the expected displacement of the whole anchorage shall be taken into account.

C.6.2 Shear load with changing sign

If the shear loads acting on the anchor change their sign several times, appropriate measures shall be taken to avoid a fatigue failure of the anchor (e.g. the shear load shall be transferred by friction between the fixture and the base material (e.g. due to a sufficiently high permanent prestressing force)).

Shear loads with changing sign can occur due to temperature variations in the fastened member (e.g. facade elements). Therefore, either these members are anchored such that no significant shear loads due to the restraint of deformations imposed to the fastened element will occur in the anchor or in shear loading with lever arm the bending stresses in the most stressed anchor $\Delta\sigma = \max\sigma - \min\sigma$ in the serviceability limit state caused by temperature variations shall be limited to 100 N/mm^2 for steel.