EOTA®

TECHNICAL REPORT

Design methods for distance fixing systems for use in concrete and masonry

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Contents

1 SCOPE OF THE TECHNICAL REPORT

The design rules in this Technical Report (TR) are only valid for anchors with a European Technical Assessment (ETA) on basis of EAD 331985-01-0604 [1].

This document relies on characteristic resistances and distances which are stated in the ETA and referred to in this TR.

The design method applies to the design of injection anchors in concrete and masonry units of clay, calcium silicate, normal weight concrete, light weight concrete, autoclaved aerated concrete (AAC) or other similar materials.

The proof of local transmission of the anchor loads into the masonry units is delivered by using the design methods described in this document. Proof of transmission of anchor loads to the supports of the masonry members shall be done by the engineer of the construction works.

The design and construction of masonry structures in which the injection anchors are to be anchored shall be comparable with the structural rules for masonry, such as EN 1996 1-1:2005 + A1:2012 Clause 3 and Clause 8 [4] and the relevant national regulations.

The design and construction of concrete structures in which the injection anchors are to be anchored shall be comparable with EN 1992-1-1 [7].

1.1 Type of anchors, anchor groups and number of anchors

The essential characteristics of the specific anchor type (characteristic values of resistance, edge distances, spacing and group factors) are given in the relevant ETA.

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.

1.2 Base material

The detailed information of the corresponding base material masonry is given in the ETA, 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), configuration of holes.

Base material concrete is defined as compacted normal weight concrete without fibres with strength classes in the range C12/15 to C90/105 all in accordance with EN 206 [11]. The range of concrete strength classes in which particular distance fixing systems may be used is given in the relevant ETA and may be more restrictive than stated above.

1.3 Type and direction of load

This Technical Report applies only to anchors subject to static or quasi-static actions in tension, shear or combined tension and shear or bending. The anchors are also intended to be used in areas with very low seismicity as defined in EN 1998-1:2004 + AC:2009, Clause 3.2.1 [5]. This Technical Report covers applications only where the masonry and concrete members, in which the anchors are embedded, are subject to static or quasi-static actions.

1.4 Specific terms used in this TR

Anchor	=	a manufactured, assembled component including bonding materials for achieving anchorage between the base material (masonry or concrete) and the fixture
Anchor group	=	several anchors (working together)
Fixture	=	component to be fixed to the masonry or concrete
Anchorage	=	an assembly comprising base material (masonry or concrete), anchor or anchor group and component fixed to the masonry or concrete

Anchors

The notations and symbols frequently used in this TR are given below. Further particular notation and symbols are given in the text.

c	=	edge distance towards the free edge of the brick or concrete (edge of the wall or vertical joint not to be filled with mortar)
c_{cr}	=	edge distance for ensuring the transmission of the characteristic resistance of a single anchor
c_{min}	=	minimum allowable edge distance
d	=	anchor bolt/thread diameter
s	=	spacing of the injection anchor
s_{cr}	=	spacing for ensuring the transmission of the characteristic resistance of a single injection anchor
$s_{cr,II}$	=	s_{cr} parallel to the horizontal joint
$s_{cr,\perp}$	=	s_{cr} perpendicular to the horizontal joint
s_{min}	=	minimum allowable spacing
t_{fix}	=	thickness of fixture

Metal parts of anchor

f_{yk}	=	nominal characteristic steel yield strength
f_{uk}	=	nominal characteristic steel ultimate strength

Loads / Forces / Resistances

P	=	pressure force
N	=	tension force
V	=	shear force
M	=	moment
$N_{Rk,}V_{Rk,}P_{Rk,}$	=	characteristic anchor resistance of a single anchor under tension or shear or pressure load
$N_{Rk,}^{g}\ V_{Rk}^{g}$	=	characteristic anchor resistance of an anchor group under tension or shear force
$N_{Ed,}^{g}\ V_{Ed,}^{g}\ P_{Ed}^{g}$	=	design value of actions acting on an anchor group
$N_{Rk,}^{h}\ V_{Rk}^{h}$	=	design value of actions acting on the highest loaded anchor

Displacements

$\delta(\delta_N, \delta_V)$	=	displacement (movement) of the anchor at the masonry surface relative to the masonry surface in direction of the load (tension, shear) outside the failure area. The displacement includes the steel and masonry deformations and a possible anchor slip.
δ_0	=	displacement of the anchor under short-term loading
δ_∞	=	displacement of the anchor under long-term loading

2 DESIGN AND SAFETY CONCEPT

2.1 Design concept

The design of anchorages shall be in accordance with the general rules given in EN 1990:2002 + A1:2005 / AC:2010 [2]. It shall be shown that the value of the design actions E_d does not exceed the value of the design resistance R_d.

$$E_d \leq R_d \qquad (1)$$

with: E_d = design value of action
R_d = design value of resistance

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 + AC 2009 [3].

The partial safety factors for actions may be taken from national regulations or in the absence of them according to EN 1990:2002 + A1:2005 / AC:2010 [2].

The design resistance is calculated as follows:

$$R_d = R_k/\gamma_M \qquad (2)$$

with: R_k = characteristic resistance of a single anchor or an anchor group
γ_M = partial safety factor for material

2.2 Ultimate limit state

The design resistance is calculated according to Equation (2).

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

Failure (rupture) of the metal part

Tension loading:

$$\gamma_{Ms} = \frac{1{,}2}{f_{yk}/f_{uk}} \geq 1{,}4 \qquad (3)$$

Shear loading of the anchor with and without lever arm:

$$\gamma_{Ms} = \frac{1{,}0}{f_{yk}/f_{uk}} \geq 1{,}25 \qquad f_{uk} \leq 800\ \text{N/mm}^2 \quad \text{and} \quad f_{yk}/f_{uk} \leq 0{,}8 \qquad (4)$$

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

Failure of the injection anchor

For use in masonry: $\gamma_{Mm} = 2{,}5$

For use in autoclaved aerated concrete: $\gamma_{MAAC} = 2{,}0$

For use in concrete: γ_M see EN 1992-4 [8]

Failure of plastic part transferring load: $\gamma_{Mtk} = 2{,}5$

Failure buckling: $\gamma_{Mca} = 1{,}3$

2.3 Serviceability limit state

In the serviceability limit state it shall be shown that the displacements occurring under the characteristic actions (see chapter 5) 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 unless specified differently in the national regulations.

3 STATIC ANALYSIS

3.1 Loads acting on anchors

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

For steel failure or failure of the plastic part transferring load 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 concrete edge or brick edge failure the shear load is assumed to act on the anchor(s) closest to the edge.

3.2 Shear loads with or without lever arm

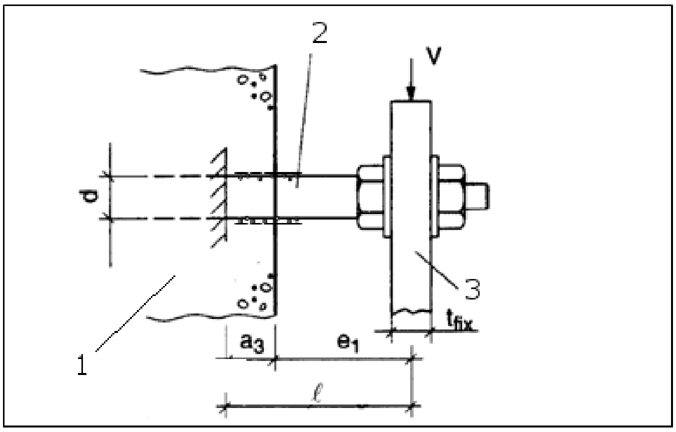
The lever arm for solid masonry and concrete is calculated according to following Equation (see Figure 1).

$$l = a_3 + e_1 \quad (5)$$

with: e_1 = distance between shear load and surface of the member

a_3 = 0,5 · d

d = diameter of the anchor bolt



1 Masonry / Concrete
2 Anchor
3 Fixture

Figure 1 – Definition of lever arm

For hollow and perforated masonry, the lever arm is defined such, that a restraint can be assumed (depending on the distance of shells).

4 ULTIMATE LIMIT STATE

4.1 Resistance to tension loads

4.1.1 Required proofs

Failure of the metal part	$N_{Ed}^{h} \leq N_{Rk,s}/\gamma_{Ms}$	EOTA TR 054 [6], 4.2.2
Pull-out failure of the anchor for base material masonry	$N_{Ed}^{h} \leq N_{Rk,p}/\gamma_{Mm}$	EOTA TR 054 [6], 4.2.3
Brick breakout failure for base material masonry	$N_{Ed} \leq N_{Rk,b}/\gamma_{Mm}$ $N_{Ed}^{g} \leq N_{Rk}^{g} / \gamma_{Mm}$	EOTA TR 054 [6], 4.2.4
Pull out of one brick and combined failure for base material masonry	$N_{Ed} \leq N_{Rk,pb}/\gamma_{Mm}$	EOTA TR 054 [6], 4.2.5
Influence of joints for base material masonry	$N_{Ed}^{h} \leq \alpha_j N_{Rk,p}/\gamma_{Mm}$ $N_{Ed} \leq \alpha_j N_{Rk,b}/\gamma_{Mm}$ $N_{Ed}^{g} \leq \alpha_j N_{Rk}^{g} / \gamma_{Mm}$	EOTA TR 054 [6], 4.2.6
Concrete cone failure	$N_{Ed} \leq N_{Rk,c}/\gamma_{Mc}$ $N_{Ed}^{g} \leq N_{Rk,c} / \gamma_{Mc}$	EN 1992-4 [8], 7.2.1.4
Combined pull-out and concrete failure	$N_{Ed} \leq N_{Rk,p}/\gamma_{Mp}$ $N_{Ed}^{g} \leq N_{Rk,p} / \gamma_{Mp}$	EN 1992-4 [8], 7.2.1.6
Concrete splitting failure	$N_{Ed} \leq N_{Rk,sp}/\gamma_{Msp}$ $N_{Ed}^{g} \leq N_{Rk,sp} / \gamma_{Msp}$	EN 1992-4 [8], 7.2.1.7
Failure of plastic part transferring load	$N_{Ed} \leq N_{Rk,tk}/\gamma_{Mtk}$	4.1.2

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

4.1.2 Failure of plastic part transferring load

The characteristic resistance of the plastic part transferring load $N_{Rk,tk}$ is given in the relevant ETA.

4.2 Resistance to pressure loads

4.2.1 Required proofs

Brick breakout failure for base material masonry	$P_{Ed} \leq \alpha_{pressure} \cdot N_{Rk,b}/\gamma_{Mm}$ $P_{Ed}^{g} \leq \alpha_{pressure} \cdot N_{Rk}^{g} / \gamma_{Mm}$	4.2.2
Failure in concrete	Design in accordance with EN 1992-4 ($\alpha_{pressure}$ is 1.0).	
Failure of plastic part transferring load	$P_{Ed} \leq P_{Rk,tk}/\gamma_{Mtk}$	4.2.3
Buckling of cantilever arm	$P_{Ed} \leq P_{Rk,ca}/\gamma_{Mca}$	4.2.4

4.2.2 Breakout failure for base material masonry

The characteristic resistance of one anchor in case of brick breakout failure $N_{Rk,b}$ and the corresponding values for spacing and edge distance $s_{cr,II}$, $s_{cr,\perp}$ and c_{cr} or c_{min} and the factor for resistance to pressure failure $\alpha_{pressure}$ are given in the relevant ETA.

The characteristic resistance of a group of two or four injection anchors N_{Rk}^{g} and the corresponding values for spacing and edge distance $s_{min,II}$, $s_{min,\perp}$ and c_{min} and the factor for resistance to pressure failure $\alpha_{pressure}$ are given in the relevant ETA.

Unless otherwise specified in the ETA, the characteristic resistance of a group with spacing smaller than $s_{cr,II}$ und $s_{cr,\perp}$ ($s_{min} \leq s \leq s_{cr}$) can be assumed to be at least the characteristic resistance of a corresponding single anchor.

4.2.3 Failure of plastic part transferring load

The characteristic resistance of the plastic part transferring load $P_{Rk,tk}$ is given in the relevant ETA.

4.2.4 Buckling of cantilever arm

The characteristic resistance of the cantilever arm $P_{Rk,ca}$ is given in the relevant ETA.

For pressure loads and pre-deformation of the distance fixing system (e. g. from imperfections) a more precise proof according to Theory II. Order is necessary. The deformations from pre-deformation at the cantilever arm have to be considered (see also 4.4.3, Equation (7) with V_{Ed}= 0).

4.3 Resistance to shear loads

4.3.1 Required proofs

Failure of the metal part, shear load without lever arm (for masonry and concrete)	$V_{Ed}^{h} \leq V_{Rk,s}/\gamma_{Ms}$	EOTA TR 054 [6], 4.3.2
Failure of the metal part, shear load with lever arm (for masonry and concrete)	$V_{Ed}^{h} \leq V_{Rk,s,M}/\gamma_{Ms}$	EOTA TR 054 [6], 4.3.3
Local brick failure for base material masonry	$V_{Ed} \leq V_{Rk,b}/\gamma_{Mm}$ $V_{Ed}^{g} \leq V_{Rk,b}^{g} / \gamma_{Mm}$	EOTA TR 054 [6], 4.3.4
Brick edge failure for base material masonry	$V_{Ed} \leq V_{Rk,c}/\gamma_{Mm}$ $V_{Ed}^{g} \leq V_{Rk,c}^{g} / \gamma_{Mm}$	EOTA TR 054 [6], 4.3.5
Pushing out of one brick for base material masonry	$V_{Ed} \leq V_{Rk,pb}/\gamma_{Mm}$	EOTA TR 054 [6], 4.3.6
Influence of joints for base material masonry		EOTA TR 054 [6], 4.3.7
Concrete pry-out failure	$V_{Ed} \leq V_{Rk,cp}/\gamma_{Mcp}$ $V_{Ed}^{g} \leq V_{Rk,cp} / \gamma_{Mcp}$	EN 1992-4 [8], 7.2.2.4
Concrete edge failure	$V_{Ed} \leq V_{Rk,c}/\gamma_{Mc}$ $V_{Ed}^{g} \leq V_{Rk,c} / \gamma_{Mc}$	EN 1992-4 [8], 7.2.2.5
Failure of plastic part transferring load	$V_{Ed} \leq V_{Rk,tk}/\gamma_{Mtk}$	4.3.2

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

4.3.2 Failure of plastic part transferring load

The characteristic resistance of the plastic part transferring load $V_{Rk,tk}$ is given in the relevant ETA.

4.4 Resistance to combined loads

4.4.1 Resistance to combined tension and shear loads

The verification of failure under combined tension and shear loads shall be done

a) steel failure: in accordance with EN1992-4:2018 section 7.2.3.1. equation 7.54.
b) concrete failure: in accordance with EN1992-4:2018 section 7.2.3.1. equation 7.55 or 7.56.
c) masonry failure: in accordance with EOTA TR 054 section 4.4

4.4.2 Buckling of cantilever arm: Resistance to combined pressure and shear loads

For combined pressure and shear loads the following equations shall be satisfied:

$$P_{Ed}\,(V_{Ed}) \leq \frac{P_{Rk,ca}\,(V)}{\gamma_{Mca}} \qquad (6)$$

with: $P_{Ed}\,(V_{Ed})$ = design values of acting combined pressure and shear load

$P_{Rk,ca}\,(V)$ = characteristic resistance to pressure load of the cantilever arm, given in the relevant ETA as a function of the acting shear load.

For combined pressure and shear loads and pre-deformation of the distance fixing system (e. g. from imperfections) a more precise proof according to Theory II. Order is necessary. The deformations from shear load and pre-deformation at the cantilever arm have to be considered. If suitable measures, such as providing an installation instruction or inspection after installation, are taken to avoid pre-deformation, the verification under consideration of pre-deformation may be omitted.

$$\left(\frac{P_{Ed}\,(V_{Ed})}{\frac{P_{Rk,ca}}{\gamma_{Mca}}}\right) + \left(\frac{V_{Ed} + \frac{P_{Ed}\cdot e_k}{l}}{\frac{V_{Rk,ca}}{\gamma_{Mca}}}\right) \leq 1{,}0 \qquad (7)$$

with: $P_{Rk,ca}$, $V_{Rk,ca}$ = given in the relevant ETA

e_k = Deflection at the end of the lever arm resulting from imperfections, theory II. Order and deformation from shear load, analogous to EN1993-1-1 section 5.3.4

$P_{Ed}\,(V_{Ed})$ = design values of acting combined pressure and shear load according to Equation (6)

4.4.4 Plastic part (thermal de-coupling): Resistance to combined normal and shear loads

For combined normal and shear loads the following equations shall be satisfied:

$$\frac{N_{Ed}}{N_{Rd}} + \frac{V_{Ed}}{V_{Rd}} \leq 1 \qquad (8)$$

with

N_{ed}, V_{Ed} = design values of combined acting normal and shear loads. Normal forces can be in compression (-) or tension (+),

N_{Rd}, V_{Rd} = design resistances against normal and shear loads. Normal resistances can be those against compression or tension. (see 4.1.2 and 4.2.3)

5 SERVICEABILITY LIMIT STATE

5.1 Displacements

The characteristic displacements of the anchor under defined tension (δ_{N0}; $\delta_{N\infty}$), and shear loads without lever arm (δ_{V0}; $\delta_{V\infty}$) and shear loads with lever arm ($\delta_{V,ca,0}$; $\delta_{V,ca,\infty}$) shall be taken from the ETA. 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 and the following equation can be used to verify service limit state:

$$\frac{\Sigma\,\delta_N(N_{Ed})}{\delta_{cr,N}} \leq 1 \qquad (9)$$

$$\frac{\Sigma\,\delta_V(V_{Ed})}{\delta_{cr,V}} \leq 1 \qquad (10)$$

$$\left[\frac{\Sigma\,\delta_N(N_{Ed})}{\delta_{cr,N}}\right]^2 + \left[\frac{\Sigma\,\delta_V(V_{Ed})}{\delta_{cr,V}}\right]^2 \leq 1^* \qquad (11)$$

with

$\Sigma\delta_N(N_{ed})$, $\Sigma\delta_V(V_{ed})$ = displacements caused by normal design loads or shear loads based on δ_{N0}; $\delta_{N\infty}$; δ_{V0}; $\delta_{V\infty}$; $\delta_{V,ca,0}$; $\delta_{V,ca,\infty}$ given in the ETA

$\delta_{cr,N}$, $\delta_{cr,V}$ = critical displacements for normal or shear loads, e.g. for crack free of rendering or water tightness

Note: The design loads for Service Limits State are usually determined with a safety factor γ_F=1.0, see section 2.3.

Verification (11) may be omitted if the determination of the critical deformations is based on a two-dimensional (2-D) consideration (calculation or test), figure 2.

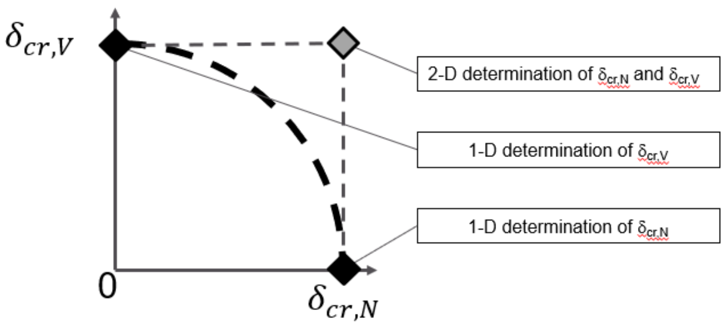


Figure 2 – Determination of critical displacements – one dimensional (1-D) and two dimensional (2-D)

Figure 2 shows different concepts of the determination of critical displacements. For an anchor system suitable for shear loads and normal loads critical displacements may have been determined by two different one-dimensional tests or calculation (1-D) – one test with a pure shear displacement and another test with a pure normal displacement. Otherwise, critical displacements may have been determined by only one two-dimensional test or calculation where the shear displacement and normal displacement is applied at the same time.

5.2 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.

Shear loads with changing sign can occur due to temperature variations in the fastened member (e.g. facade elements). Therefore, 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.

6 THERMAL BRIDGE VERIFICATION

The effect of mechanical fasteners at the thermal insulation layer must be taken into account when determining the thermal transmittance U according to EN ISO 6946 [9]. The corrected thermal transmittance U_c results from the following equation:

$$U_c = U + \Delta U_f + \Delta U_g \qquad (12)$$

with:
- U: thermal transmittance of the undisturbed wall
- ΔU_f: correction for anchors
- ΔU_g: correction for air gaps according to EN ISO 6946 [9], F.2

According to EN ISO 6946 [9], F.3.1, the correction of the thermal transmittance for mechanical fasteners is calculated as follows:

$$\Delta U_f = n_f \cdot \chi \qquad (13)$$

with:
- n_f: number of fasteners per m^2
- χ: point thermal transmittance according to ETA

The point thermal transmittance χ can also be calculated with a 3D model according to EN ISO 10211:2008-04 [10]. In this case the equivalent thermal conductivity λ_{eq} according to ETA shall be used for the glass fibre reinforced plastic element including the connecting screw.

However, if the total correction ($\Delta U_f + \Delta U_g$) is less than 3% of U, no correction is necessary.

7 REFERENCE DOCUMENTS

[1] EAD 331985-01-0604: Distance fixing systems, pre-draft December 2020

[2] EN 1990:2002 + A1:2005 / AC:2010: Basis of structural design

[3] EN 1991:2002 + AC 2009: Actions on structures

[4] EN 1996-1-1:2005 + A1:2012: Design of masonry structures. Part 1-1: General rules for reinforced and unreinforced masonry structure

[5] EN 1998-1:2004 + AC:2009: Design of structures for earthquake resistance – Part 1: General rules, seismic actions and rules for buildings

[6] EOTA TR 054:2016-04, amended 2022-07: Design methods for anchorages with metal injection anchors for use in masonry

[7] EN 1992-1-1:2004 + AC:2010: Design of concrete structures – Part 1-1: General rules and rules for buildings

[8] EN 1992-4:2018: Design of concrete structures - Part 4: Design of fastenings for use in concrete

[9] EN ISO 6946:2017: Building components and building elements - Thermal resistance and thermal transmittance - Calculation methods

[10] EN ISO 10211:2017: Thermal bridges in building construction - Heat flows and surface temperatures - Detailed calculations

[11] EN 206:2013 + A1 2016: Concrete: Specification, performance, production and conformity