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TECHNICAL REPORT

Recommendations for tests of metal injection anchors for use in masonry to be carried out on construction works

TR 053

April 2016

Amended July 2022

EUROPEAN ORGANISATION FOR TECHNICAL ASSESSMENT

WWW.EOTA.EU

Contents

1 GENERAL

The recommendations in this Technical Report (TR) are only valid for metal injection anchors with a European Technical Assessment (ETA) on basis of EAD 330076-00-0604 [6], EAD 330076-01-0604 [1] or EAD 330076-01-0604-v01 [4].

The recommendations apply to tests of metal injection anchors in masonry units of clay, calcium silicate, normal weight concrete, light weight concrete, autoclaved aerated concrete (AAC) to be carried out on construction works.

The characteristic resistances given in an ETA for use in solid masonry can be applied only to masonry composed of the same brick types or masonry units with identical or larger size and compressive strength, for masonry mortar with equal or larger compressive strength, and for identical or larger edge distances and spacing conditions.

The characteristic resistances given in an ETA for use in hollow or perforated masonry can be applied only to masonry composed of the same brick or block types with identical configuration of the voids, with identical or larger size and compressive strength, for masonry mortar with equal or larger compressive strength, and for identical or larger edge distances and spacing conditions.

In the absence of national requirements, the characteristic resistance of the injection anchor may be determined by the following so-called "job site tests", if the injection anchor has an ETA with characteristic values for the same type of base material (e.g., clay, calcium silicate, normal weight concrete, lightweight aggregate concrete, or autoclaved aerated concrete) as is present on the construction works.

Furthermore, job site tests for use in solid masonry are possible only if the injection 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 injection anchor has an ETA for use in hollow or perforated masonry.

The tension and shear characteristic resistances to be applied to an injection anchor should be determined by means of tests carried out on the construction work with a centric tension or shear load, respectively. These tests may also be performed in a laboratory under equivalent conditions as used on construction work.

Execution and evaluation of the tests as well as issue of the test report and determination of the characteristic resistance should be supervised by the person responsible for execution of works on site and be carried out by an engineer experienced in anchorages and masonry work.

The position of the injection anchors to be tested should be adapted to the relevant special conditions of the construction work in question and, the minimum number of tests performed for example in blind and larger areas, should be increased such that reliable information about the characteristic resistance of the injection anchor embedded in the considered base material can be derived. The tests shall take account of the unfavourable conditions of practical execution.

2 ASSEMBLY

The injection anchor to be tested should be installed (e.g., preparation of drill hole, drilling tool to be used, drill bit, type of drilling hammer or rotation, thickness of fixture) and as far as spacing and edge distances are concerned be distributed in the same way as foreseen for the intended use.

Depending on the drilling tool, hard metal hammer-drill bits or hard metal percussion drill bits according to ISO 5468:2006 [2] should be used.

The installation process (including cleaning of the drill hole) shall follow the manufacturer's installation instruction using the tools given in the corresponding ETA.

3 EXECUTION AND EVALUATION OF TESTS

3.1 General

The characteristic resistance under tension and shear loading may be determined by tension pull-out tests to failure according to 3.2.2 or tension proof-load tests according to 3.2.3 (for evaluation of shear resistance see section 3.3.1). Optionally, the shear load resistance may be determined separately by specific shear tests to failure according to section 3.3.3 or by shear proof-load tests according to section 3.3.4. The characteristic resistances F_{Rk1} or F_{Rk2} have to be equal to or smaller than the characteristic resistance F_{Rk} which is given in the ETA for the same type of masonry (bricks or blocks).

In absence of national regulations, the partial safety factors for the resistance of the injection anchor may be taken as $\gamma_{M,AAC}$ = 2,0 for use in autoclaved aerated concrete and γ_{Mm} = 2,5 for use in all other masonry units. Further information is given in section 3.4.

3.2 Characteristic value of tension resistance

3.2.1 General tension test conditions

The test rig used for the tests under tension loading should allow a continuous slow increase of load recorded by measuring equipment with a measuring error of 5% at maximum throughout the whole measuring range.

The load should act perpendicular to the surface of the base material and be transmitted to the injection anchor via a hinge. The reaction forces should be transmitted to the base material such that possible breakout of the masonry is not restricted. This condition is considered as fulfilled, if the support reaction forces are transmitted at a distance of at least 1,5hef from the installed anchors (i.e. support diameter/ width 3hef) and, for small sized bricks, to adjacent masonry units that are not in direct contact with the unit where the anchor is installed (see Figure 3.2 b)).

To facilitate testing on site the support diameter (widths) a_{dist} may be chosen smaller than $3h_{ef}$ for embedment depths smaller than or equal to 150 mm, provided that the resistances are reduced by a factor α_{dist} according to Equation (3.1) (see also Figure 3.1). In this case, the minimum support diameter (width) is limited to $1{,}5h_{ef}$.

$$\alpha_{dist} = 0{,}4 + (a_{dist} / 5h_{ef}) \tag{3.1}$$

where:

α_{dist} = reduction factor for support diameters (widths) $1{,}5h_{ef} \leq a_{dist} < \min(3{,}0h_{ef}; 450\text{ mm})$ and $h_{ef} \leq 150$ mm (see Figure 3.1)

a_{dist} = actual support diameter (clear width) in on-site test

h_{ef} = effective embedment depth (here limited to ≤ 150 mm)

For embedment depths larger than 150 mm in multiple wythes walls featuring solid bricks of limited dimensions, e.g., solid clay bricks, no reduction is required for smaller support diameters, provided that the above conditions on support width and free development of failure modes are kept. This also applies to resistances obtained from anchors located in masonry mortar joints and to hollow or perforated bricks, where local failure modes are expected (e.g., anchor pull-out).

In addition to the above requirements, the test support for anchorages in hollow or perforated bricks shall not be located on the same brick along the direction of the perforation of the brick (i.e., either vertically or horizontally) to allow a full breakout of the penetrated web(s) of the brick (see Figure 3.2 a)).

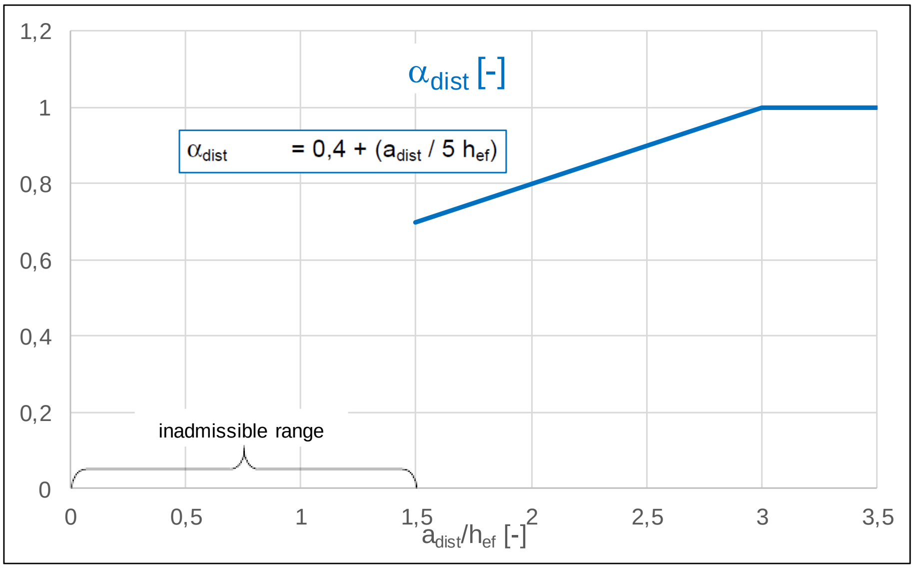
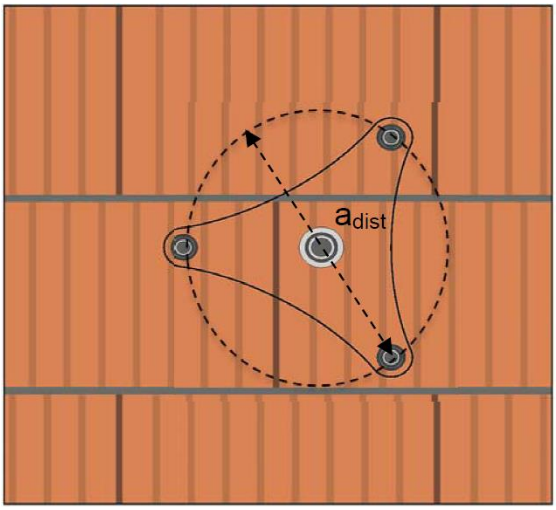
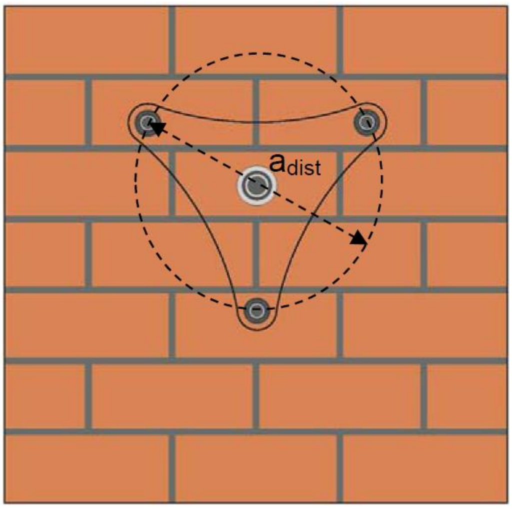


Figure 3.1: Reduction factor α_{dist} for $h_{ef} \leq 150$ mm and small support width



a) Hollow and perforated bricks (large brick size)



b) Small sized bricks

Note: Only for point support be assumed to extend to the axis of the support. In all other cases, especially for continuous supports, a_{dist} shall be equal to the clear width.

Figure 3.2: Examples of support configurations

3.2.2 Tension pull-out tests to failure

3.2.2.1 Execution of pull-out tests

The minimum number of pull-out tests is 5.

The load should be progressively increased so that the ultimate load is achieved after not less than about 1 minute. Recording of the ultimate load shall be carried out in each single test.

3.2.2.2 Evaluation of the results of the pull-out tests

If the number of pull-out tests is equal to or more than 15, the characteristic resistance N_{Rk1} in case of static and quasi-static actions may be obtained from the measured values of N_1 as follows:

$$N_{Rk1} = \alpha_{dist} \cdot 0{,}7 \cdot \beta \cdot N_1 \leq N_{Rk,ETA} \qquad (3.2)$$

where:

α_{dist} = reduction factor according to section 3.2.1

N_1 = mean value of the five smallest measured values at ultimate load

β = factor to consider the different influences of the product as given in the ETA for static or quasi-static actions

$N_{Rk,ETA}$ = characteristic tension resistance N_{Rk} for static and quasi-static action as given in the ETA for the same kind of masonry

If the number of pull-out tests is smaller than 15 or in case of seismic design, the characteristic values shall be determined as a 5 %-fractile according to equation (3.3), taking into account the factors β or $\alpha_{N,seis}$ as given in the ETA for the corresponding base material and type of action (e.g., static or quasi-static, seismic).

$$N_{Rk1} = \alpha_{dist} \cdot N_{Rm} \cdot (1 - k_s \cdot v) \cdot \beta_{ETA} \leq N_{Rk,ETA} \quad (3.3)$$

where:

α_{dist} = reduction factor according to section 3.2.1

N_{Rm} = mean value of the ultimate load of all tests

v = coefficient of variation of the ultimate load

β_{ETA} = factor to consider the different influences of the product as given in the ETA

= β in case of static or quasi-static actions

= $\alpha_{N,seis}$ in case of seismic actions

$N_{Rk,ETA}$ = characteristic tension resistance N_{Rk} given in the ETA for the same kind of masonry and type of action (static and quasi-static or seismic)

k_s = statistical factor for determination of 5% fractile as given in Table 3.1.

Table 3.1: Factor k_s depending on number of tests n

n	5	6	7	8	9	10	11	12	13	14	15	20	25	30
k_s [1)]	3,40	3,09	2,89	2,75	2,65	2,57	2,50	2,45	2,40	2,36	2,33	2,21	2,13	2,08
[1)] under the assumption of a normal distribution and unknown standard deviation on a confidence level of 90% (see [5]; also for k_s-values for different number of tests)														

3.2.3 Tension proof-load tests

The target of the proof load test is to define a load level below failure to limit the damage to the base material.

3.2.3.1 Execution of proof-load tests

The minimum number of proof-load tests is 15.

The required proof-load $N_{p,req}$, to be applied shall be determined according to Equation (3.4) and not exceed the value given by Equation (3.5). The load shall be progressively increased until the proof load $N_{p,req}$ is achieved after at least one minute and kept constant at this level for at least another minute. The actual applied load shall be recorded. If in tests a lower load than given by Equation (3.4) has been applied (see also note below), the actual applied minimum load of all tests, N_p, shall be considered in Equation (3.6) leading to a lower characteristic tension resistance N_{Rk2}.

In case of a slight drop in load ($< 0{,}1N_{p,req}$) due to setting of the equipment (e.g. uneven surface or sand grain), a single re-increase of the applied load is possible to allow a constant loading for at least one further minute. If further load drops are observed, the test shall be considered as unsuccessful, and the target load must be reduced until these requirements are kept.

$$N_{p,req} \geq N_{Ed} \cdot \gamma_M \cdot 1/(\alpha_{dist} \cdot \beta_{ETA}) \quad (3.4)$$

$$N_{p,req} \leq N_{Rk,ETA}/(\alpha_{dist} \cdot \beta_{ETA}) \quad (3.5)$$

where:

$N_{p,req}$ = required load for tension proof load tests

N_{Ed} = design value of action ($N_{Ek} \cdot \gamma_F$)

γ_M = partial safety factors for the resistance
γ_{MAAC} = 2,0 for autoclaved aerated concrete,
γ_{Mm} = 2,5 for all other masonry units

α_{dist} = reduction factor according to section 3.2.1

β_{ETA} and $N_{Rk,ETA}$ as given in section 3.2.2.2

Note: To reduce the probability of failure in the proof-load test, it may be reasonable to limit the proof-load to a reduced value of the characteristic resistance in accordance with the ETA for the reference brick/block (e.g., $N_{p,req} \leq 0{,}8 \quad N_{Rk,ETA}/(\alpha_{dist} \quad \beta_{ETA})$).

3.2.3.2 Evaluation of the results of proof-load tests

If visible movement or displacement of the injection anchors does not occur in all tests under the applied proof-load constantly kept for one minute (exceptions see previous section 3.2.3.1), then an estimate for the characteristic resistance N_{Rk2} may be obtained as follows:

$$N_{Rk2} = \alpha_{dist} \cdot N_p \cdot \beta_{ETA} \leq N_{Rk,ETA} \quad (3.6)$$

where:

N_p = (minimum) applied constant load in tension proof load tests

α_{dist} = reduction factor according to section 3.2.1

β_{ETA} and $N_{Rk,ETA}$ as given in section 3.2.2.2

3.3 Characteristic value of shear resistance

3.3.1 Evaluation of shear resistances from tension testing

If no specific shear tests are performed on site, one of the following requirements should be applied for determination of the characteristic shear resistances depending on the availability of tension tests.

3.3.1.1 Evaluation of results of pull-out tests

For shear loads it can be assumed:

if $V_{Rk,ETA} \geq N_{Rk,ETA}$: $V_{Rk1} = N_{Rk1} \leq V_{Rk,c}$

if $V_{Rk,ETA} < N_{Rk,ETA}$: $V_{Rk1} = N_{Rk1} \cdot (V_{Rk,ETA} / N_{Rk,ETA}) \leq V_{Rk,c}$

where:

N_{Rk1} = see Equation (3.2) or (3.3)

$N_{Rk,ETA}$ = characteristic tension resistance N_{Rk} given in the ETA for the same kind of masonry and type of action (for static and quasi-static or seismic)

$V_{Rk,ETA}$ = characteristic shear V_{Rk} given in the ETA for the same kind of masonry and type of action (for static and quasi-static or seismic)

$V_{Rk,c}$ = characteristic resistance for brick edge failure according to TR 054 [3], section 4.3.5 (for static or quasi-static action) or section 6.7 (for seismic actions), respectively, for $c \geq c_{cr}$.

3.3.1.2 Evaluation of the results of tension proof-load tests

For shear loads it can be assumed:

if $V_{Rk,ETA} \geq N_{Rk,ETA}$: $V_{Rk2} = N_{Rk2} \leq V_{Rk,c}$

if $V_{Rk,ETA} < N_{Rk,ETA}$: $V_{Rk2} = N_{Rk2} \cdot (V_{Rk,ETA} / N_{Rk,ETA}) \leq V_{Rk,c}$

where:

N_{Rk2} = see Equation (3.6)

$N_{Rk,ETA}$, $V_{Rk,ETA}$ and $V_{Rk,c}$, see section 3.2.2.2 and 3.3.1.1, respectively.

3.3.2 General shear test conditions

The test rig used for the tests shear loading should allow a continuous slow increase of load recorded by calibrated measuring equipment with a measuring error of 5% at maximum throughout the whole measuring range.

The load should act perpendicular to the axis of the anchor and parallel to the surface of the base material. It should be transmitted to the injection anchor via a fixture with maximum inner through hole diameter as specified in the corresponding ETA and a fixture (clamping) thickness of approximately the outside diameter of the anchor.

To simplify testing under shear load, the filling of the annular gap, if intended for the application, e.g., with a high-strength mortar or by other means (special steel element), may be omitted in the context of the job-site tests, if the tests are executed without annular gap (i.e., clearance hole in the fixture = outer nominal diameter of steel element). If there is an annular gap, at the start of the tests the anchor shall be in direct contact with the fixture on the side where the shear load is applied.

The shear resistances are valid only for the tested loading direction (vertical/ perpendicular to bed joint or horizontal/ parallel to bed joint) and edge distances. The reaction forces should be transmitted to the base material such that possible breakout of the masonry is not restricted. In case of shear loading towards a free edge, the supports shall be spaced at a distance of at least 1,5 times the edge distance c away from the axis of the shear loading (total support width: 3c) and, in addition for hollow or perforated bricks, the supports shall rest only on bricks adjacent to the one the test anchor is installed in.

3.3.3 Shear tests to failure

3.3.3.1 Execution of shear tests to failure

The minimum number of shear tests to failure is 5.

The load should be progressively increased so that the ultimate load is achieved after not less than about 1 minute. At least, recording of the ultimate load shall be carried out in each single test.

3.3.3.2 Evaluation of the results of the shear tests to failure

If the number of shear tests is equal to or more than 15, the characteristic resistance V_{Rk1} in case of static and quasi-static actions may obtained from the measured values of V_1 as follows:

$$V_{Rk1} = 0{,}7 \cdot V_1 \cdot \beta \leq V_{Rk,ETA} \qquad (3.7)$$

where:

V_1 = mean value of the five smallest measured values at ultimate load; single values up to a displacement of 20 mm

β = factor to consider the different influences of the product as given in the ETA for static or quasi-static actions

$V_{Rk,ETA}$ = characteristic shear resistance V_{Rk} for static and quasi-static action as given in the ETA for the same kind of masonry

If the number of shear tests is smaller than 15 or in case of seismic design, the characteristic values shall be determined as a 5 %-fractile according to equation(3.8), taking into account the factors β or $\alpha_{V,seis}$ as given in the ETA for the corresponding base material and type of action (e.g., static or quasi-static, seismic).

$$V_{Rk1} = V_{Rm} \cdot (1 - k_s \cdot v) \cdot \beta_{ETA} \leq V_{Rk,ETA} \qquad (3.8)$$

where:

V_{Rm} = mean value of the ultimate load of all tests; single values up to a displacement of 20 mm

v = coefficient of variation of the ultimate load

β_{ETA} = factor to consider the different influences of the product as given in the ETA

= β in case of static or quasi-static actions

= $\alpha_{V,seis}$ in case of seismic actions

$V_{Rk,ETA}$ = characteristic shear resistance V_{Rk} given in the ETA for the same kind of masonry and type of action (static and quasi-static or seismic)

k_s = statistical factor for determination of 5% fractile as given in Table 3.1.

3.3.4 Shear proof-load tests

The target of the proof load test is to define a load level below failure to limit the damage to the base material.

3.3.4.1 Execution of shear proof-load tests

The minimum number of shear proof-load tests is 15.

The required proof-load $V_{p,req}$, to be applied shall be determined according to Equation (3.9) and not exceed the value given by Equation (3.10). The load shall be progressively increased until the proof load $V_{p,req}$ is achieved after at least one minute and kept constant at this level for at least another minute. The actual applied load shall be recorded. If in tests a lower shear load than given by Equation (3.9) has been applied (see also note below), the actual applied minimum shear load of all tests, V_p, shall be considered in Equation (3.11) leading to a lower characteristic shear resistance V_{Rk2}.

In case of a slight drop in load (< $0{,}1V_p$) due to setting of the equipment (e.g. uneven surface or sand grain), a single re-increase of the applied load is possible to allow a constant loading for at least one further minute. If further load drops are observed, the test shall be considered as unsuccessful, and the target load must be reduced until these requirements are kept.

$$V_{p,req} \geq V_{Ed} \cdot \gamma_M \cdot 1/\beta_{ETA} \quad (3.9)$$

$$V_{p,req} \leq V_{Rk,ETA}/\beta_{ETA} \quad (3.10)$$

where:

$V_{p,req}$ = required load for shear proof load tests

V_{Ed} = design value of action ($N_{Ek} \cdot \gamma_F$)

γ_M = partial safety factors for the resistance
γ_{MAAC} = 2,0 for autoclaved aerated concrete,
γ_{Mm} = 2,5 for all other masonry units

β_{ETA} and $V_{Rk,ETA}$ as given in section 3.3.3.2

Note: To reduce the probability of failure in the proof-load test, it may be reasonable to limit the proof-load to a reduced value of the characteristic load-bearing capacity according to ETA for the reference brick/block (e.g., $V_{p,req} \leq 0{,}8 \quad V_{Rk,ETA}/ \beta_{ETA}$).

3.3.4.2 Evaluation of the results of shear proof-load tests

If visible movement or displacement of the injection anchors does not occur in all tests under the applied proof-load constantly kept for one minute (exceptions see previous section3.3.4.1), then an estimate for the characteristic shear resistance V_{Rk2} may be obtained as follows:

$$V_{Rk2} = V_p \cdot \beta_{ETA} \leq V_{Rk,ETA} \quad (3.11)$$

where:

V_p = (minimum) applied constant load in shear proof load tests

β_{ETA} and $V_{Rk,ETA}$ as given in section 3.3.3.2

3.4 Partial safety factors for resistance

Depending on the test carried out on-site, the partial safety factors for the resistances listed in Table 3.2 may be used in design in the absence of national regulations.

Table 3.2 Partial safety factor for resistance γ_M

Brick types used in masonry		15 Proof-load tests according to section 3.2.3 (tension) or 3.3.4 (shear) or for shear resistances evaluated according to section 3.3.1	≥ 5 tests to failure according to section 3.3.2 (tension) or 3.3.3 (shear)
Clay, calcium silicate, normal weight concrete and lightweight aggregate concrete	γ_{Mm}	2,5	2,25
AAC	γ_{MAAC}	2,0	1,8

4 TEST REPORT

The test report should include all information necessary to assess the resistance of the tested injection anchor. It should be given to the person responsible for the design of the fastening. The following information is necessary e.g.:

Name of product

Construction work

Building owner

Date and place of tests

Test rig

Type of structure to be fixed

Masonry (type of brick, strength class, all dimensions of bricks and mortar group if possible);
Visual assessment of masonry (flush joints, joint clearance, regularity);
Thickness of plaster layer or intervening layer (e.g. insulation), if existing

Injection anchors

Cutting diameter of hard metal hammer-drill bits

Type of used drill method (hammer drill, impact drill, core drill)

Cleaning process of the drill hole in detail

Results of tests including indication of value N_1 or N_p; mode of failure

Results of tests including indication of value V_1 or V_p; mode of failure

Tests carried out or supervised by; Signature

5 REFERENCE DOCUMENTS

As far as no edition date is given in the list of standards thereafter, the standard in its current version at the time of issuing the European Technical Assessment is of relevance.

[1] EAD 330076-01-0604: Metal injection anchors for use in masonry, May 2021.

[2] ISO 5468:2006: Rotary and rotary impact masonry drill bits with hard metal tips - Dimensions.

[3] EOTA: Technical Report TR 054: Design methods for anchorages with metal injection anchors for use in masonry, April 2016, last amended July 2022.

[4] EAD 330076-01-0604-v01: Metal Injection Anchors For Use In Masonry Under Seismic Actions, September 2021.

[5] Owen, D.: Handbook of Statistical Tables. Addison/ Wesley Publishing Company Inc., 1968.

[6] EAD 330076-00-0604: Metal injection anchors for use in masonry, April 2016