



TECHNICAL REPORT

Details of tests for
post-installed fasteners
in concrete

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1 SCOPE

This Technical Report provides details for the tests with post-installed fasteners in concrete.

2 NOTATION

a	= Length of square base plate according to Table 3.2
a'	= Length of attachment according to Figure 3.16
A_s	= stressed cross-section of the fastener used for determining the tensile capacity
A_5	= fracture elongation
b	= width of concrete member
c	= Edge distance according to Figure 3.9
d	= fastener bolt / thread diameter
d_0	= drill hole diameter
d_{cut}	= cutting diameter of drill bit
$d_{cut,m}$	= medium cutting diameter of drill bit (see Figure 3.5)
$d_{cut,max}$	= cutting diameter at the upper tolerance limit (see Figure 3.5) (maximum diameter bit)
$d_{cut,min}$	= cutting diameter at the lower tolerance limit (see Figure 3.5) (minimum diameter bit)
d_f	= diameter of clearance hole in the fixture
d_2	= diameter of expanded undercut fastener
f_c	= concrete compressive strength measured on cylinders
$f_{c,cube}$	= concrete compressive strength measured on cubes with a side length of 150 mm
$f_{c,cube100}$	= concrete compressive strength measured on cubes with a side length of 100 mm
$f_{c,cube200}$	= concrete compressive strength measured on cubes with a side length of 200 mm
f_{cm}	= mean concrete compressive strength
h	= thickness of the concrete member
h_{ef}	= effective embedment depth
h_{nom}	= overall fastener embedment depth in the concrete
M	= medium size of the complete product range of each fastener type as supplied to the market
N_p	= Tensile load applied during the test
$N_{Rk,s,fi}$	= Characteristic resistance to steel failure under fire exposure
N_s	= Force applied to the test member to control the crack width according to 3.3.3
R_{p02}	= 0,2% yield limit according to EN ISO 898-1
s_{min}	= minimum allowable spacing
T_{inst}	= required or maximum recommended setting torque specified by the manufacturer for expansion or pre-stressing of fastener
t	= Profile thickness according to Table 3.2
t_{fix}	= thickness of fixture
t_u	= Thickness of the cover according to Figure 3.16
z	= Distance between flanges according to Table 3.2
Δw_1	= Upper limit of crack width according to Figure 3.11
Δw_2	= Lower limit of crack width according to Figure 3.11

- $\Delta\sigma_s$ = working stroke of action in repeated load tests
 μ = Ratio of reinforcement
 ϕ = Nominal diameter of a deformed reinforcing bar

3 DETAILS OF TESTS

3.1 Test samples, test members, test setup, installation and test equipment

3.1.1 Test samples

Fasteners with inner threads may be supplied without the fixing elements such as screws or nuts, but the manufacturer of the fastener shall specify the screws or nuts to be used. If according to the chosen design method the characteristic resistance for concrete failure is needed, it may be necessary to use screws or bolts of higher strength than those specified, in order to achieve a concrete failure in tests. If higher strength screws or bolts are used, the functioning of the fasteners must not be influenced in any way. The use of such test specimens shall be clearly stated in the test report.

3.1.2 Test members

3.1.2.1 General

This Technical Report is valid for fasteners tested in concrete members using compacted normal weight concrete without fibres with strength classes in the range of C20/25 - C50/60 in accordance with EN 206 [1]. The fastener performance is only valid for the range of tested concrete.

The test members shall comply with the following:

3.1.2.2 Aggregates

Aggregates shall be of natural occurrence (i.e. non-artificial) and with a grading curve falling within the boundaries given in Figure 3.1. The maximum aggregate size shall be 16 mm or 20 mm. The aggregate density shall be between 2.0 and 3.0 t/m³ (see EN 206 [1] and ISO 6783 [3]).

The boundaries reported in Figure 2.1 are valid for aggregate with a maximum size of 16 mm. For different values of maximum aggregate sizes, different boundaries may be adopted, if previously agreed with the responsible TAB.

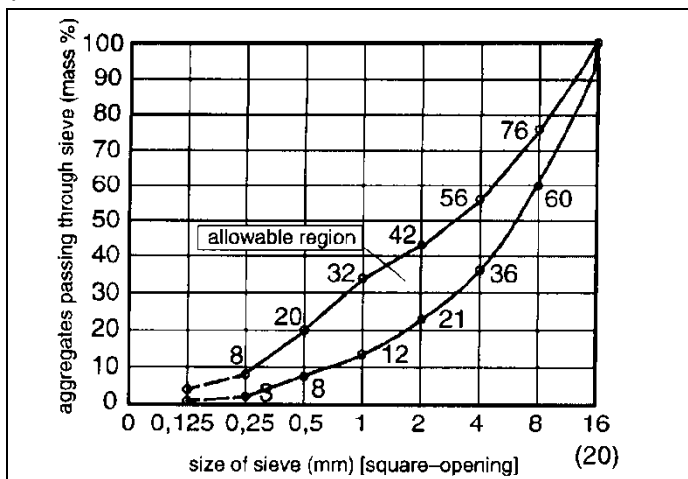


Figure 3.1 Admissible region for the grading curve

3.1.2.3 Cement

The concrete shall be produced using Portland cement Type CEM I or Portland-Composite cement Type CEM II/A-LL, CEM II/B-LL (see EN 197-1 [4])

3.1.2.4 Water/cement ratio and cement content

The water/cement ratio shall not exceed 0,75 and the cement content shall be at least 240 kg/m³.

No additives likely to change the concrete properties (e.g. fly ash, or silica fume or other powders) shall be included in the mixture.

3.1.2.5 Concrete strength

For the tests carried out in low strength concrete (strength class C20/25) and high strength concrete (strength class C50/60) the following mean compressive strengths at the time of testing fasteners shall be obtained for the two classes:

C20/25	f_c	=	20-30 MPa (cylinder: diameter 150 mm, height 300 mm)
	f_{cube}	=	25-35 MPa (cube: 150 x 150 x 150 mm)
C50/60	f_c	=	50-60 MPa (cylinder: diameter 150 mm, height 300 mm)
	f_{cube}	=	60-70 MPa (cube: 150 x 150 x 150 mm)

It is recommended to measure the concrete compressive strength either on cylinders with a diameter of 150 mm and height of 300 mm, or on cubes of 150 mm.

The following conversion factors for concrete compressive strength from cube to cylinder may be used:

$$\text{C20/25} \quad f_c = \frac{1}{1,25} f_{cube} \quad (3.1)$$

$$\text{C50/60} \quad f_c = \frac{1}{1,20} f_{cube} \quad (3.2)$$

For other dimensions, the concrete compressive strength may be converted as follows:

$$f_{cube100} = \frac{1}{0,95} f_{cube} \quad (3.3)$$

$$f_{cube} = \frac{1}{0,95} f_{cube200} \quad (3.4)$$

$$f_{cube} = f_{core100} \text{ (acc. to EN 13791 [2], section 7.1)} \quad (3.5)$$

Note 1: Additional literature for conversion is given by R. Lewandowski, [13]

For every concreting operation, specimens (cylinder, cube) shall be prepared having the dimensions conventionally employed in the member country. The specimens shall be made, cured and conditioned in the same way as the test members.

Generally, the concrete control specimens shall be tested on the same day as the fasteners to which they relate. If a test series takes a number of days, the specimens shall be tested at a time giving the best representation of the concrete strength at the time of the fastener tests, e.g. at the beginning and at the end of the tests. In this case the concrete strength at the time of testing can be determined by interpolation.

The concrete strength at a certain age shall be measured on at least 3 specimens. The mean value of the measurements governs.

If, when evaluating the test results, there should be doubts whether the strength of the control specimens represents the concrete strength of the test members, at least three cores of 100 mm diameter shall be taken from the test members outside the zones where the concrete has been damaged in the tests, and tested in compression. The cores shall be cut to a height equal to their diameter, and the surfaces to which the compression loads are applied shall be ground or capped. The compressive strength measured on these cores may be converted into the strength of cubes by equation (3.5).

3.1.2.6 Test members for tests in cracked concrete

The tests are carried out on test members with unidirectional cracks. The crack width shall be approximately constant throughout the member thickness. The thickness of the test member shall be $h \geq 2 h_{ef}$ but at least 100 mm. To control cracking, so-called 'crack-formers' may be built into the member, provided they are not situated near the anchorage zone. An example for a test member is given in Figure 3.2.

In the test with variable crack width the reinforcement ratio (top and bottom reinforcement) shall be $\mu = A_s / (b \cdot h) \sim 0,01$ and the spacing of the bars ≤ 250 mm.

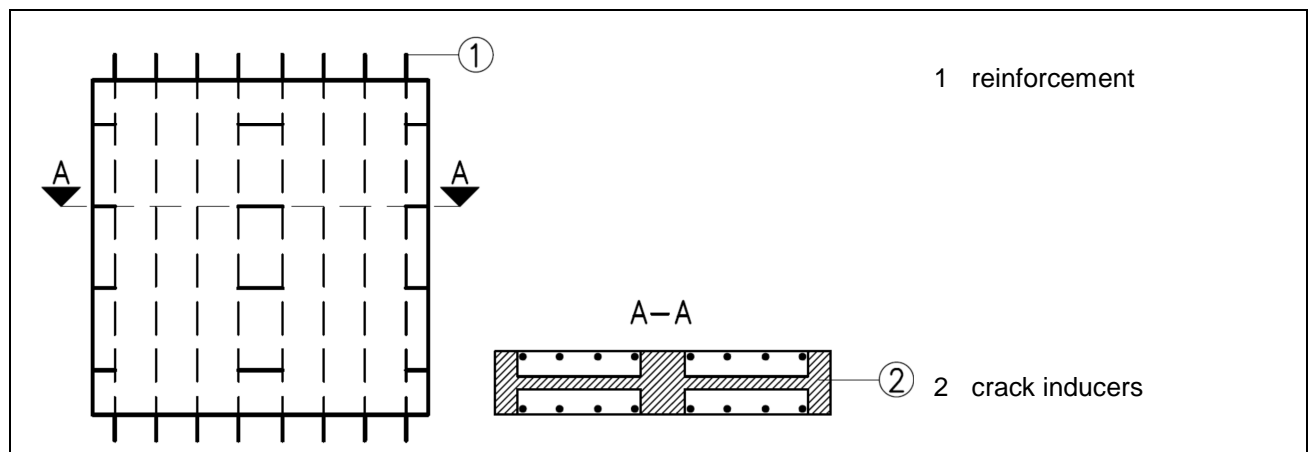


Figure 3.2 Example of a test member for fasteners tested in cracked concrete

3.1.2.7 Test members for tests in uncracked concrete

Generally, the tests are carried out on unreinforced test members. In cases where the test member contains reinforcement to allow handling or for the distribution of loads transmitted by the test equipment, the reinforcement shall be positioned such as to ensure that the loading capacity of the tested fasteners is not affected. This requirement will be met if the reinforcement is located outside the zone of concrete cones having a vertex angle of 120° .

3.1.2.8 Casting and curing of test members

The test members shall be cast horizontally. They may also be cast vertically if the maximum height is 1,5 m and complete compaction is ensured.

Test members and concrete specimens (cylinders, cubes) shall be cured and stored indoors for seven days. Thereafter they may be stored outside provided they are protected such that frost, rain and direct sun does not cause a deterioration of the concrete compression and tension strength. When testing the fasteners the concrete shall be at least 21 days old.

Test members and concrete specimen shall be stored in the same way.

3.1.3 Unconfined test setup

Unconfined tests allow an unrestricted formation of the rupture concrete cone. An example for an unconfined test setup is shown in Figure 3.3.

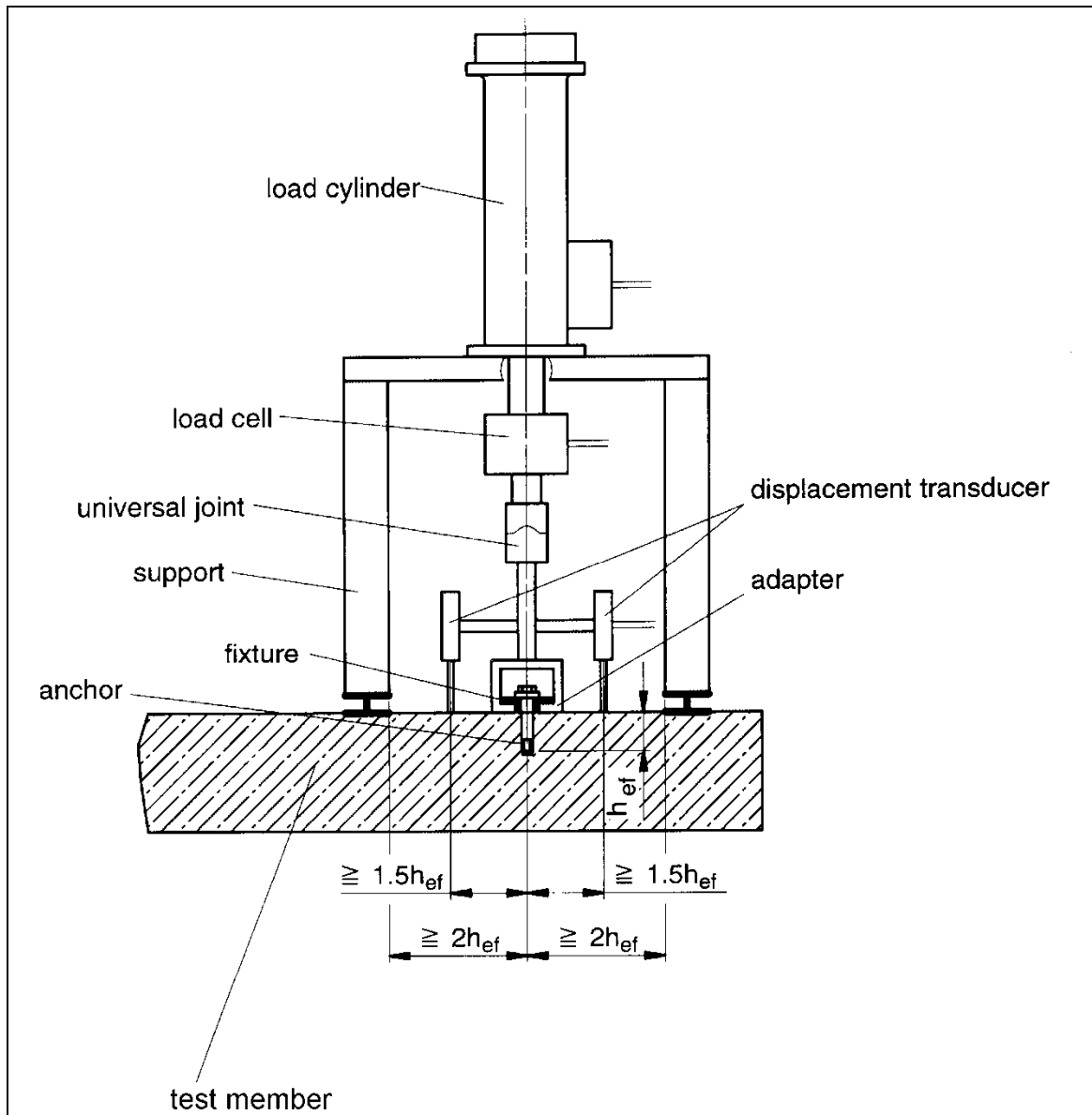


Figure 3.3 Example of a tension test rig for unconfined tests

3.1.4 Confined test setup

Confined tests are performed when concrete cone failure shall be excluded (e.g. for bond resistance of bonded fasteners). In confined tests concrete cone failure is eliminated by transferring the reaction force close to the fastener into the concrete.

An example of the test setup is shown in Figure 3.4. The rig / steel plate shall be stiff and the area of support large to avoid high compression of the concrete. Recommendation: compression strength under the steel plate < 0,7 of the concrete compression strength.

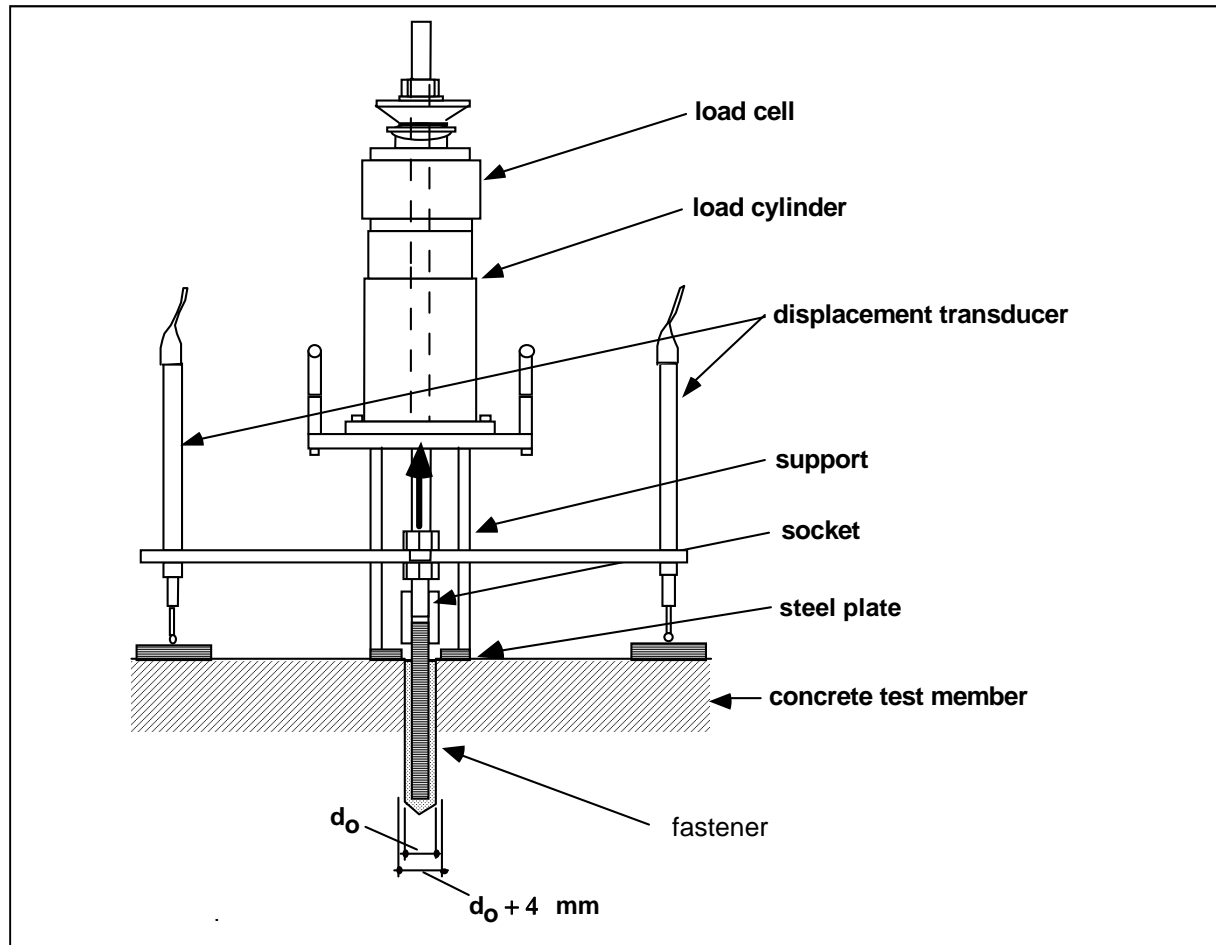


Figure 3.4 Example of a tension test rig for confined tests

3.1.5 Installation of fasteners

The tested fasteners shall be installed in a concrete surface that has been cast against a form of the test member.

The fasteners shall be installed in accordance with the manufacturer's product installation instructions (MPII), except where special conditions are specified in the EAD for the test series.

Torque moments, where appropriate, shall be applied to the fastener by a torque wrench that has a documented calibration. The measuring error shall not exceed 5 % of the applied torque throughout the whole measurement range.

For torque controlled fasteners, about 10 minutes after torquing the fasteners with the torque moment T_{inst} required by the manufacturer, the torque moment shall be reduced to $0,5 T_{inst}$ to account for relaxation of the pre-stressing force with time.

Fasteners not needing the application of a defined torque moment (e.g. deformation-controlled expansion fasteners, many types of undercut fasteners and bonded fasteners) shall be finger-torqued before testing.

With fasteners which need to be torqued, the test results can be influenced by the roughness of the fixture. Therefore the washer shall not turn relative to the fixture. To ensure defined test conditions, e.g. double-sided abrasive material may be inserted between washer and fixture (see Figure 3.8).

For the tests for "robustness to installation" only special conditions appropriate for the fastener types concerned are specified in the corresponding EAD or section of this technical report.

When testing in cracked concrete, fasteners are placed in the middle of hairline cracks. It shall be verified that the fastener is placed over the entire anchoring zone in the crack by suitable methods (e.g. borescope).

The holes for fasteners shall be perpendicular ($\pm 5^\circ$ deviation) to the surface of the concrete member.

In the tests the drilling tools specified by the manufacturer for the fasteners shall be used. If hard metal hammer-drill bits are required, these bits shall meet the requirements laid down in ISO 5468 [8] with regard to dimensional accuracy, symmetry, symmetry of insert tip, height of tip and tolerance on concentricity.

The diameter of the cutting edges as a function of the nominal drill bit diameter is given in Figure 3.5. The EADs specify the required cutting diameter of drill bits ($d_{cut,min}$, $d_{cut,max}$, $d_{cut,m}$) for the test series.

The diameter of the drill bit shall be checked every 10 drilling operations to ensure continued compliance.

If special drilling bits like stop-drills or diamond core drill bits are required no standards on the specification of these products are available. In this case the manufacturer of the fastener has to specify the dimensions and tolerances of the bits and tests shall be performed with bits within the specifications. The definition of a required or corresponding diameter shall be laid down by the responsible TAB.

Note 1: The tolerances need also be defined and specified for alternate drilling method for which no standards exist. These tolerances need to be specified in the ETA (so that it is known for which tolerances the performance has been evaluated) as well as in the MPII (in order to be able to stay within these tolerances on the job site).

Note 2: Furthermore, the diamond drilling tool may have an influence on the performance of mechanical fasteners (e.g. expansion fasteners) and bonded fasteners as it affects the geometry of the hole. One may need to specify the diamond drilling tool for which the fastener has been assessed in the ETA.

For concrete screws the reduction of the torque is not required.

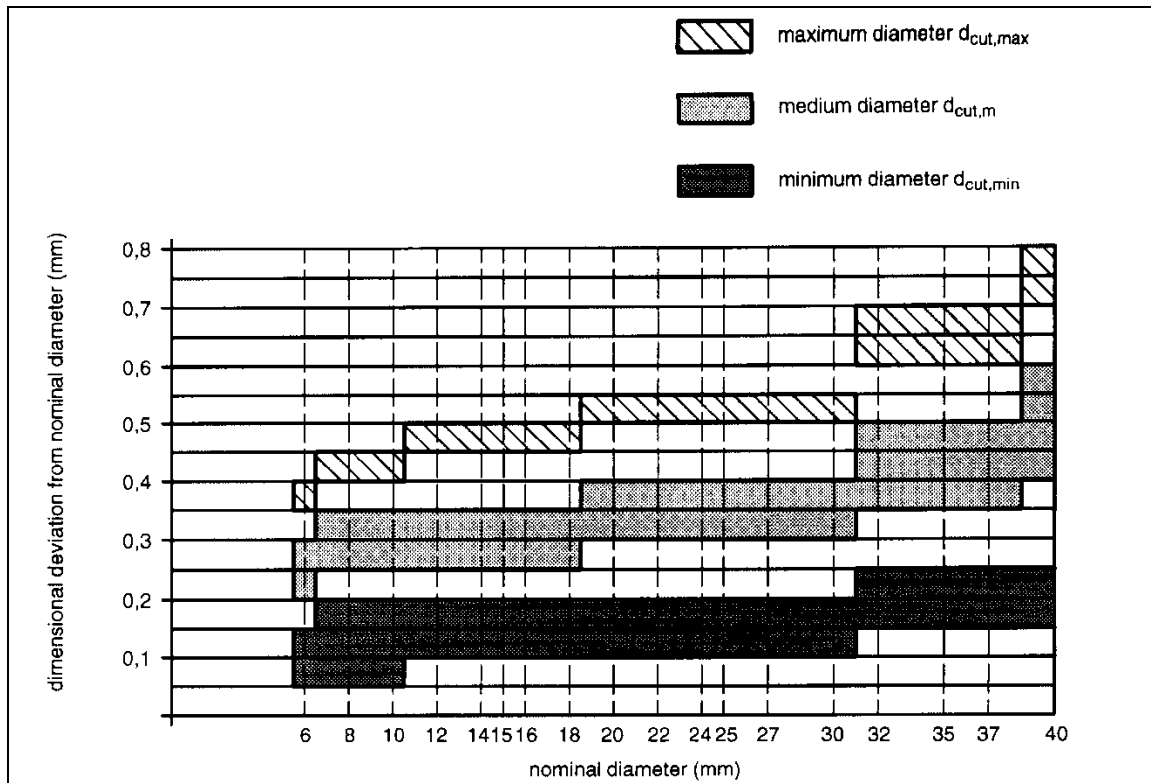


Figure 3.5 Cutting diameter of hard metal hammer-drill bits

3.1.6 Test equipment

Tests shall be carried out using measuring equipment having a documented calibration according to international standards. The load application equipment shall be designed to avoid sudden increase in load especially at the beginning of the test. The measurement bias of the measuring chain of the load shall not exceed 2% of the measured quantity value.

Displacements shall be recorded continuously (e.g. by means of electrical displacement transducers) with a measuring bias not greater than 0,020 mm or 2,0 % for displacements > 1 mm.

For unconfined tests the test rigs shall allow the formation of an unrestricted rupture cone. For this reason the distance between the support reaction and a fastener (single fastener) or an outer fastener (fastener group) respectively shall be at least $2 h_{ef}$ (tension test) as shown in Figure 3.3 or $2 c_1$ (shear test at the

edge with load applied towards the edge, with c_1 = edge distance in load direction) as shown in Figure 3.7. Only in shear tests without edge influence where steel failure is expected this distance may be less than $2 c_1$.

During all tests, the load shall be applied to the fastener by a fixture representing the conditions found in practice.

In tests on single fasteners without edge and spacing influences the centre-to-centre distance and the distances from free edges shall be large enough to allow the formation of an unrestricted rupture cone of vertex angle 120° in the concrete.

During tension tests the load shall be applied concentrically to the fastener. To achieve this, hinges shall be incorporated between the loading device and the fastener. Requirements for the diameter of the clearance hole of the fixture may be given in the EADs. An example of a tension test rig is illustrated in Figure 3.3.

In shear tests (see 3.6), the load shall be applied parallel to the concrete surface. A plate with interchangeable sleeves may be used for testing the different sizes of fasteners (see Figure 3.6). The sleeves shall be made of quenched steel and have radiused edges (0,4 mm) where in contact with the fastener. The height of the sleeves shall be approximately equal to the outside diameter of the fastener. To reduce friction, smooth sheets (e.g. PTFE) with a maximum thickness of 2 mm shall be placed between the plate with sleeve and the test member.

An example of a shear test rig is illustrated in Figure 3.7. As there is a lever arm between the applied load and the support reaction, the test member is stressed by a torsion moment. This shall be taken up by additional reaction forces placed sufficiently far away from the fastener.

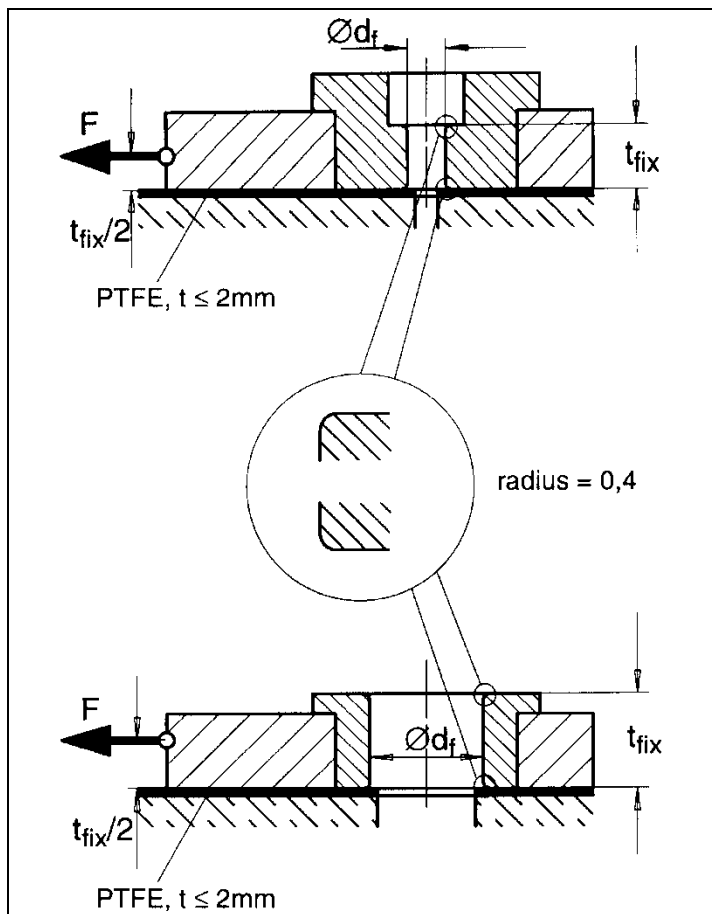


Figure 3.6 Examples of shear test sleeves

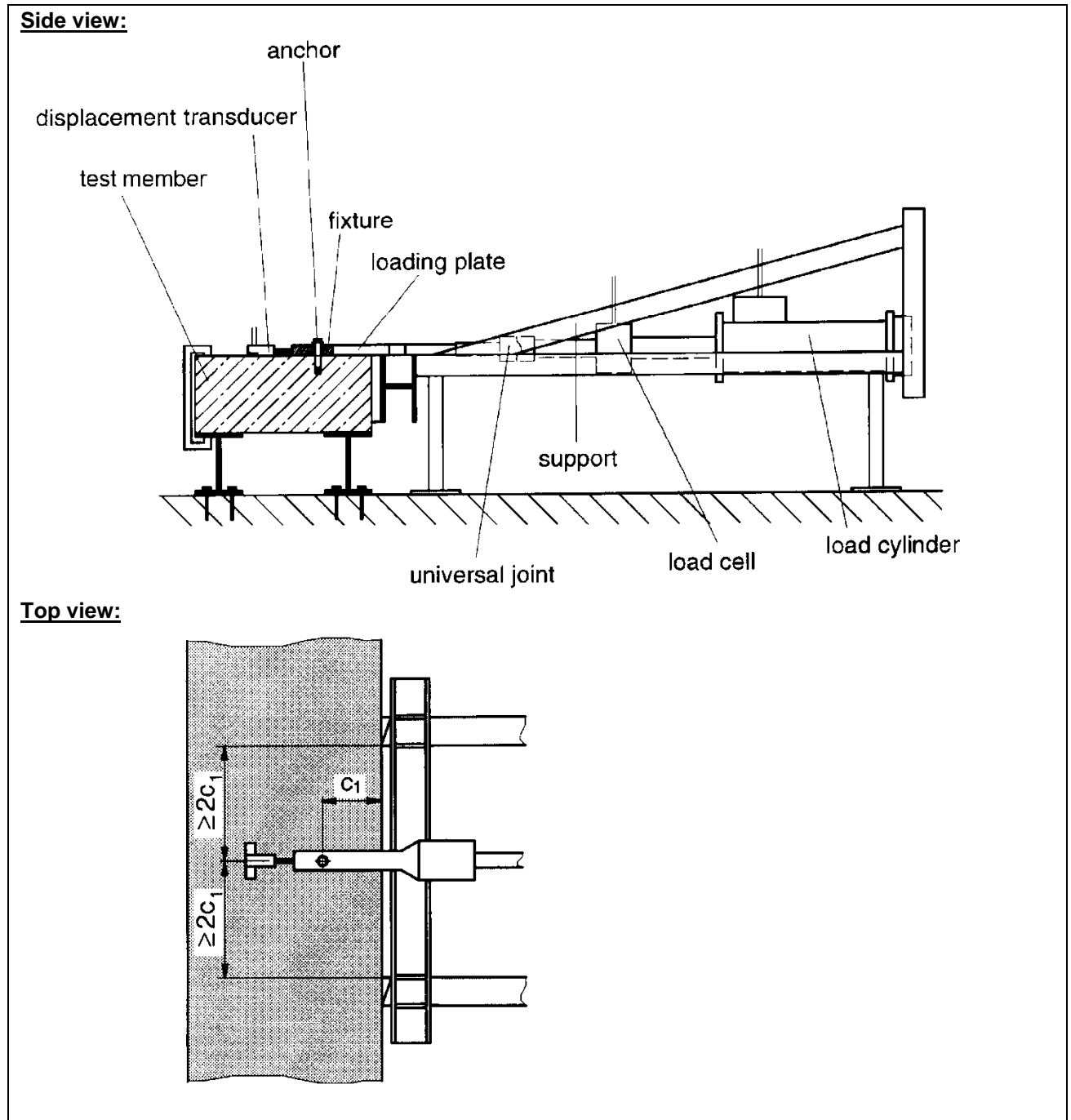


Figure 3.7 Example of a shear test rig

In torque tests (see 3.5) the relation between the applied torque moment and the tension force in the bolt is measured. For this, a calibrated load cell with a measuring error $\leq 3,0\%$ throughout the whole measuring range is used as a fixture (see Figure 3.8).

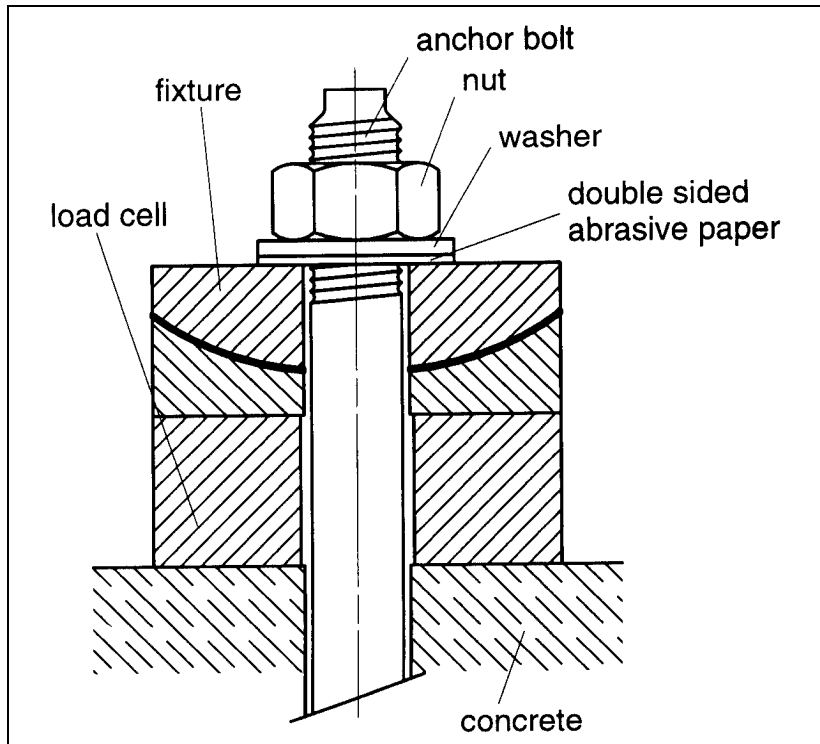


Figure 3.8 Example for torque test (schematic)
Any rotation of the spherical part of the fixture shall be prevented.

3.2 Test procedure – general aspects

The fasteners shall be installed in accordance with the MPII, except where special conditions are specified in the EAD for the test series.

The tests in cracked concrete are undertaken in unidirectional cracks. The required crack width Δw is given in the relevant EAD. Δw is the difference between the crack width when loading the fastener and the crack width at fastener installation. After installation of the fastener the crack is widened to the required crack width while the fastener is unloaded. The initial crack width shall be set to within $+10\%$ of the specified value. However, the mean value of a series shall reflect the specified value.

Use one-sided tolerance for crack width.

Then the fastener is subjected to load while the crack width is controlled, either

- at a constant width, for example, by means of a servo system, or
- limited to a width close to the initial value by means of appropriate reinforcement and depth of the test member.

In both cases the crack width at the face opposite to that through which the fastener is installed be maintained at a value larger than or equal to the specified value.

The load shall be increased in such a way that the peak load occurs after 1 to 3 minutes from commencement. Load and displacement shall be recorded continuously. The tests may be carried out with load, displacement or hydraulic control. In case of displacement control the test shall be continued beyond the peak of the load/displacement curve to at least 75% of the maximum load to be measured (to allow the drop of the load/displacement curve). In case of displacement controlled test setup the speed shall be kept constant.

The data shall be collected with a frequency of 3 Hz – 5 Hz.

3.3 Tension tests

3.3.1 Single fastener under tension load

After installation, the fastener is connected to the test rig and loaded to failure. The displacements of the fastener relative to the concrete surface shall be measured by use of either one displacement transducer on the head of the fastener or by use of at least two displacement transducers on either side at a distance of $\geq 1,5 h_{ef}$ from the fastener; the mean value of the transducer readings shall be recorded in the latter case.

When testing fasteners at the corner of a non-cracked test member, the test rig shall be placed such that an unrestricted concrete failure towards the corner is possible (see Figure 3.9). It may be necessary to support the test rig outside the test member.

When testing in cracked concrete, the crack width shall be regularly measure during the test on both sides of the fastener at a distance of approximately $1,0 h_{ef}$ and at least on the face of the test member in which the fasteners are installed.

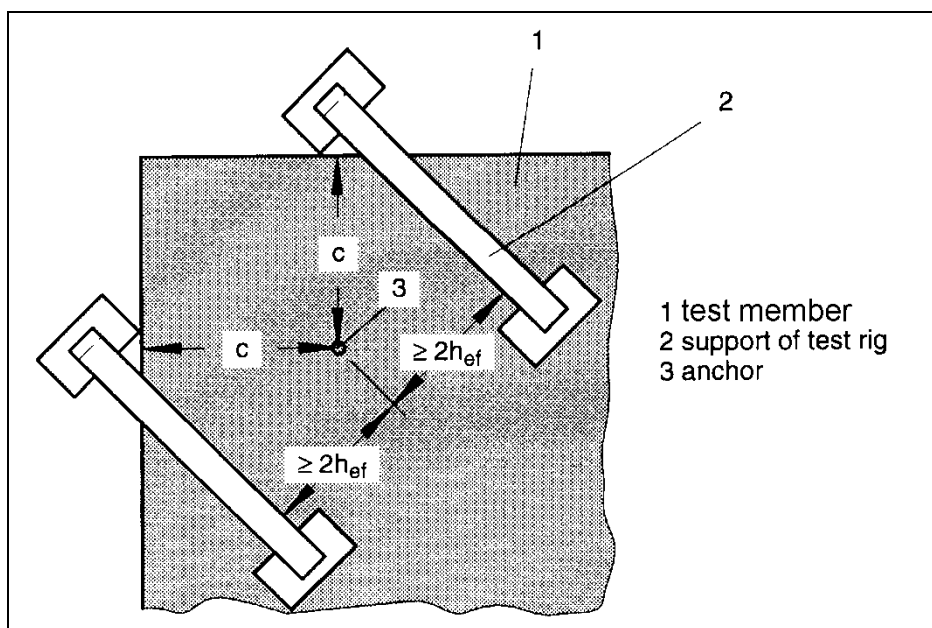


Figure 3.9 Example of the test rig for tension tests on fasteners at a corner

3.3.2 Robustness to contact with reinforcement

For tests with robustness to contact with reinforcement the specimen shall be reinforced with smooth bars (bar diameter $\phi = 25$ mm, spacing $a > 150$ mm). The concrete cover shall correspond to the value $h_{ef} - \phi / 2$ (so that the effective embedment depth is at the same depth as the axis of the bar).

When drilling the cylindrical hole, the drilling tool shall be mounted in a drilling stand and positioned such that the reinforcing bar is clearly cut. On the average the depth of the notch cut shall be 1 mm. Apart from the contact with reinforcement the fastener shall be installed according to the MPII. Then a tension test shall be performed.

A fastener after installation in contact with reinforcement is shown in Figure 3.10.

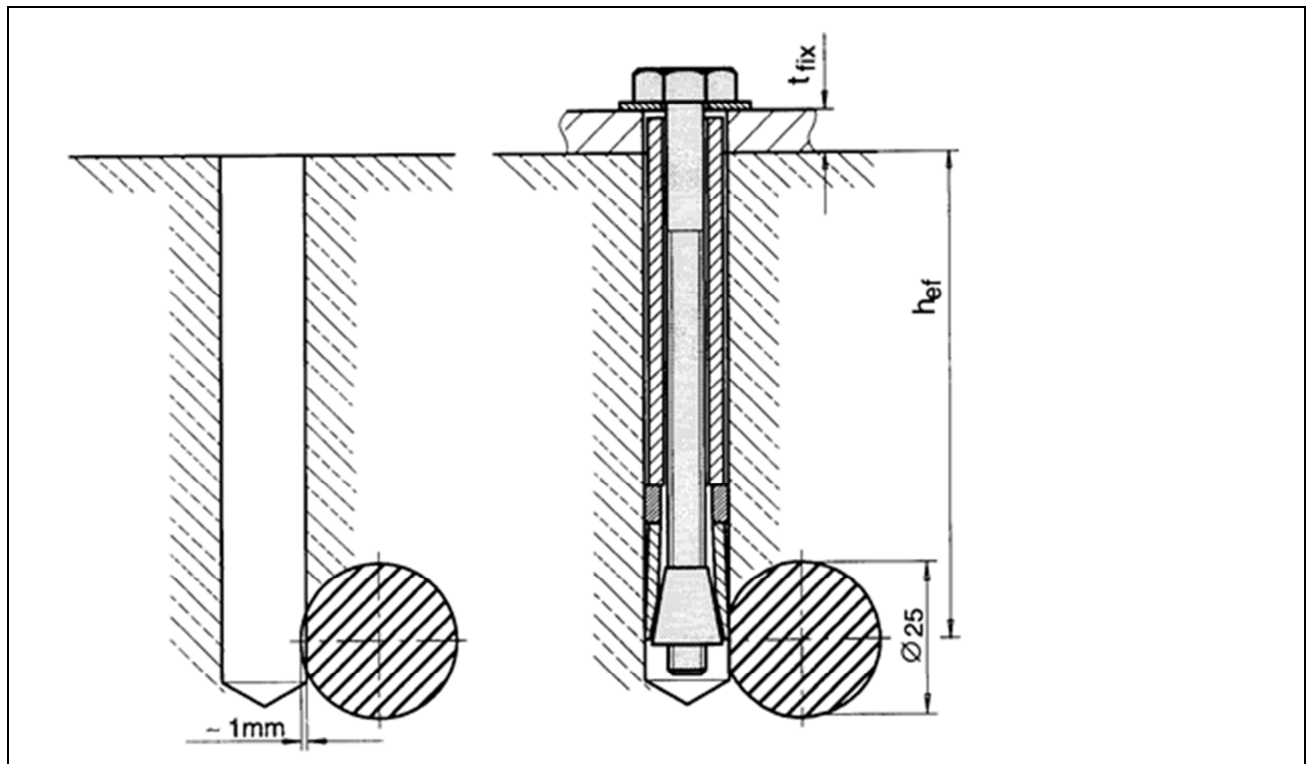


Figure 3.10 Position of fastener when tested in contact with reinforcement

3.3.3 Crack cycling under load

After installation of the fastener the maximum ($\max N_s$) and minimum ($\min N_s$) loads applied to the test member shall be determined such that the crack width under $\max N_s$ is $\Delta w_1 = 0,3$ mm and under $\min N_s$ is $\Delta w_2 = 0,1$ mm. To stabilize crack formation, up to 10 load changes varying between $\max N_s$ and $\min N_s$ may be applied. Then a tensile load N_p as specified in the relevant EAD is applied to the fastener after opening the crack to $\Delta w_1 = 0,3$ mm.

N_p shall remain constant during the test (variation $\pm 5\%$). Then the crack is opened and closed 1000 times (frequency approximately 0,2 Hz). During opening of the cracks, the crack width Δw_1 is kept approximately constant (see Figure 3.11); for this purpose the load $\max N_s$ applied to the test member may have to be reduced. The load $\min N_s$ is kept constant. Therefore, the crack width Δw_2 may increase during the test (see Figure 3.11). The crack width difference $\Delta w_1 - \Delta w_2$, however, shall be $\geq 0,1$ mm during the 1000 movements of the crack. If this condition cannot be fulfilled with $\Delta w_1 = 0,3$ mm, then either $\min N_s$ shall be reduced or Δw_1 shall be increased accordingly.

The load/displacement behaviour shall be measured up to the load N_p . Afterwards under N_p , the displacements of the anchor and the crack widths Δw_1 and Δw_2 shall be measured either continuously or at least after 1, 2, 5, 10, 20, 50, 100, 200, 500, 750 and 1000 crack movements.

After completion of the crack movements the anchor shall be unloaded, the displacement measured and a tension test to failure performed with $\Delta w = 0,3$ mm.

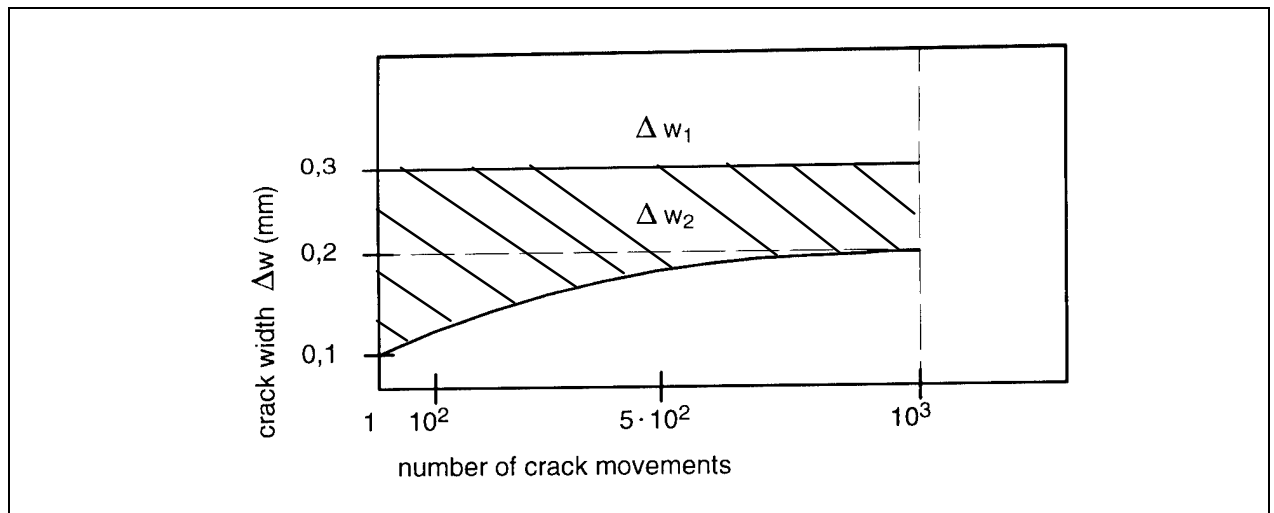


Figure 3.11 Allowable crack opening variations during the crack movement test

3.3.4 Repeated loads

The test is performed in non-cracked concrete. The fastener is subjected to 10^5 load cycles with a maximum frequency of approximately 6 Hz. During each cycle the load shall change as a sine curve between maximum and minimum value, i.e. max N and min N, respectively, given in the relevant EAD. The displacements shall be measured during the first loading up to max N and then either continuously or at least after 1, 10, 10^2 , 10^3 , 10^4 and 10^5 load cycles.

After completion of the load cycles the fastener shall be unloaded, the displacement measured and a tension test to failure performed.

Concrete screws:

For concrete screws according to EAD 330232-00-0601 [12], the tests under repeated loads according to EAD 330232-00-0601 [12], shall be modified as follows:

The concrete screw shall be set on bevelled washers (inclination angle $\geq 4^\circ$) and shall be installed according to the MPII. The corner of the hexagon nut shall rest on the bevelled washer. The position is shown in Figure 3.12. When the installation torque $T = T_{inst}$ is applied, the fastener head might just reach the bevelled washer (see Figure 3.12 b) or might be fully pressed against the washer (see Figure 3.12 c). Any position of the fastener head between the extreme positions shown in Figure 3.12 is acceptable.

If the manufacturer applies for different head forms, the fastener with the most unfavourable head form shall be tested. The greatest torque moment in the shaft and the greatest notch effect shall be considered. If the most unfavourable head form is not obvious all head forms shall be tested.

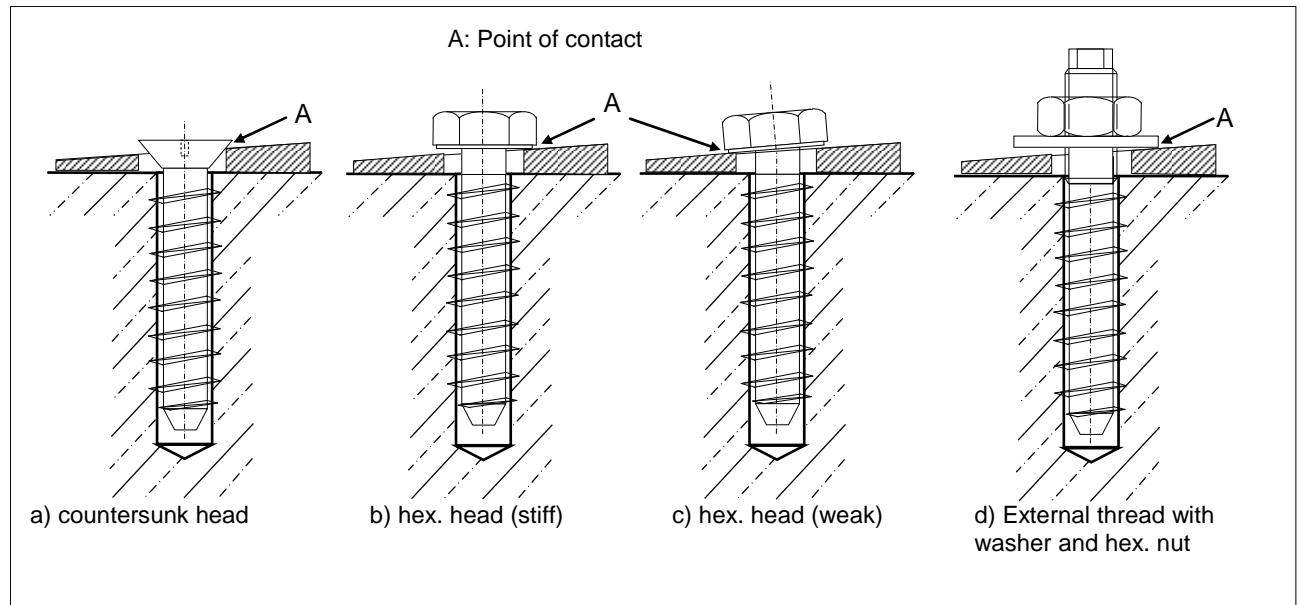


Figure 3.12 Position of the fastener head on bevelled washers in tests with repeated loads

3.4 Test for minimum edge distance and spacing

If no other specification is given in the relevant EAD, the tests shall be performed in uncracked concrete of strength class C20/25 (minimum concrete strength class).

The tests are carried out with double fasteners with a spacing $s = s_{\min}$ and an edge distance $c = c_{\min}$. The double fasteners are placed with a distance $a > 3 h_{\text{ef}}$ between neighbouring groups. The dimensions of the fixture shall be width = $3 d_f$, length = $s_{\min} + 3 d_f$ and thickness $\cong d_f$ (d_f as required in the relevant EAD).

The fasteners shall be torqued alternately in steps of $0,2 T_{\text{inst}}$. After each load step the concrete surface shall be inspected for cracks. The test is stopped when the torque moment cannot be increased further.

The number of revolutions per load step shall be measured for both fasteners. Furthermore, the torque moment at the formation of the first hairline crack at one or both fasteners and the maximum torque moment that can be applied to the two fasteners shall be recorded.

3.5 Maximum torque moment

The torque moment is applied with a calibrated torque wrench until it cannot be increased further or at least to $1,3 T_{\text{inst}}$.

The tension force in the bolt or screw shall be measured as a function of the applied torque moment.

3.6 Tests under shear load

3.6.1 Single fastener

After installation, the fastener is connected to the test rig without gap between the fastener and the interchangeable sleeve in the loading plate and is then loaded to failure. The displacements of the fastener relative to the concrete shall be measured in the direction of the load application, e.g. by use of a displacement transducer fixed behind the fastener (seen from the direction of load application) on the concrete (see Figure 3.7).

When testing in cracked concrete, 3.2 applies. However, the crack widths shall be measured at a distance of approximately h_{ef} behind the fastener. The load shall be applied in the direction of the crack towards the edge.

If the fastener is requested to be assessed for different embedment depths for a specific diameter, the most unfavourable condition shall be tested. If the most unfavourable condition cannot be determined all embedment depths have to be tested.

3.6.2 Quadruple fastener group

After installation, the 4 fasteners shall be connected by a rigid fixture with the dimension given in Figure 3.13.

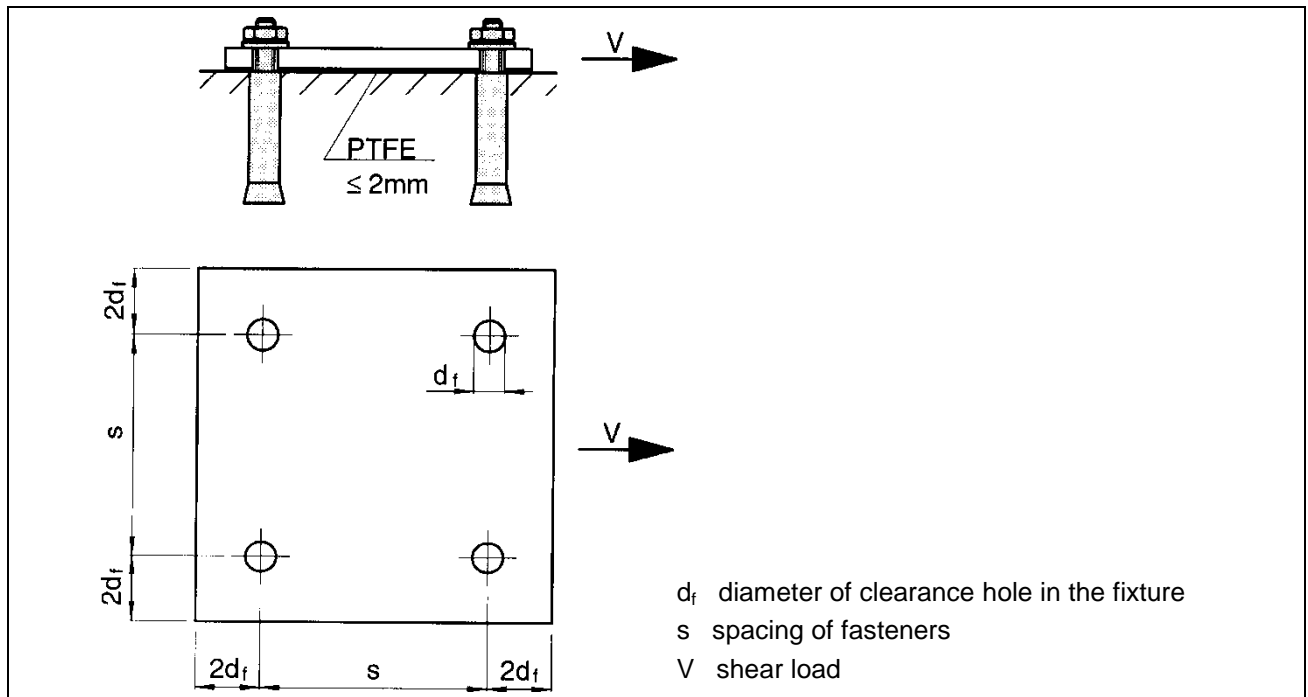


Figure 3.13 Dimensions of fixture

Below the fixture, a sheet of PTFE (sliding layer) with a maximum thickness of 2 mm shall be placed. The test arrangement shall simulate a hinged connection so that the 4 fasteners are loaded equally. The shear force may be applied to the front or back side of the fixture.

The load on the fastener group and the shear mean displacement of the fixture relative to the concrete outside the rupture cone shall be measured.

3.7 Degree of expansion for deformation-controlled expansion fasteners

In order to achieve reproducible results for deformation controlled expansion fasteners, defined conditions for the expansion shall be defined.

The fastener behaviour can be sensitive to the effectiveness of expansion. The effectiveness of fastener expansion depends on:

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

The influence of these parameters on the fastener behaviour is covered by tests with reference expansion.

Test conditions

The tests shall be performed with single fasteners, without edge and spacing effects.

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

The expansion of the fasteners is achieved by an impact device (e.g. generally in accordance with DIN 18127 [11] or with BS 1377-1 [10]), structural shape B and C. The principle test setup is shown in Figure 3.14. The impact device is kept perpendicular to the fastener 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 fastener 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 fastener axis.

Before the first blow and at least after the number of blows according to Table 3.1, lines 5 and 6, the fastener 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 / nail for cone down type fasteners (drop-in fastener), shank-down type fastener (stud fastener) and sleeve-down type fasteners. For the stud version of sleeve-down type fasteners 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 fastener to the concrete surface.

Three different expansion conditions a), b) and c) are distinguished:

- a) Full expansion:
Expansion achieved when setting the fastener according to the manufacturer's written installation instructions.
- b) Reference expansion:
Expansion achieved by applying specified expansion energy (see Table 3.1, line 5). The reference expansion is defined as the mean expansion achieved in tests with the number of applied blows in accordance with Table 3.1, line 5.
- c) Installation expansion:
Expansion achieved by applying a specified expansion energy which is reduced in relation to reference expansion. The installation expansion is defined as the mean expansion achieved with the number of applied blows in accordance with Table 3.1, line 6.

If the reference expansion and/or installation expansion is less than full expansion, these values have to be used in the relevant test series.

Machine setting:

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 3.14.

The machine setting tests shall be performed with at least 5 fasteners 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 fastener 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 average 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 average after a setting time of at maximum 15 seconds.

Table 3.1 Test conditions

1	fastener 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.	-	3	5	6	7	4	5
6	number of blows ¹⁾ for evaluation of installation expansion.	-	2	3	4	5	3	4
¹⁾ The tests are carried out with a standardized device applying a constant energy per blow. In practice, the energy applied during setting of the fastener by a hand hammer depends on the fastener size. Therefore the number of blows is different for the different fastener sizes.								

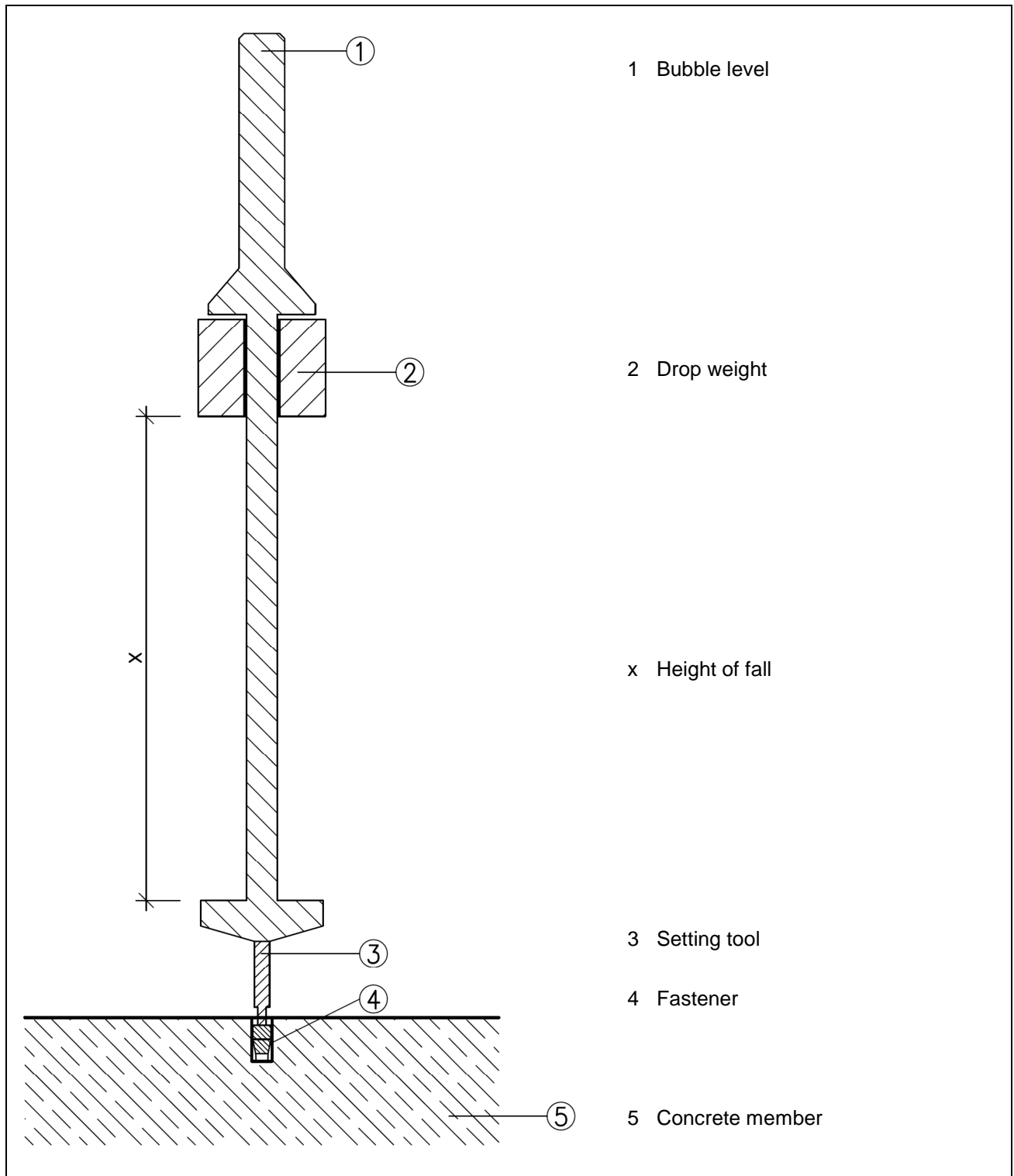


Figure 3.14 Arrangement for tests to determine the degree of expansion (schematic) – example of setting a drop-in fastener

3.8 Fire exposure

3.8.1 Tests for steel failure under tension load

Test set-up:

The tests for the determination of the carrying capacity under steel failure have to be carried out in uncracked concrete using an unloaded slab. The principle test set-up can be seen in Figure 3.15.

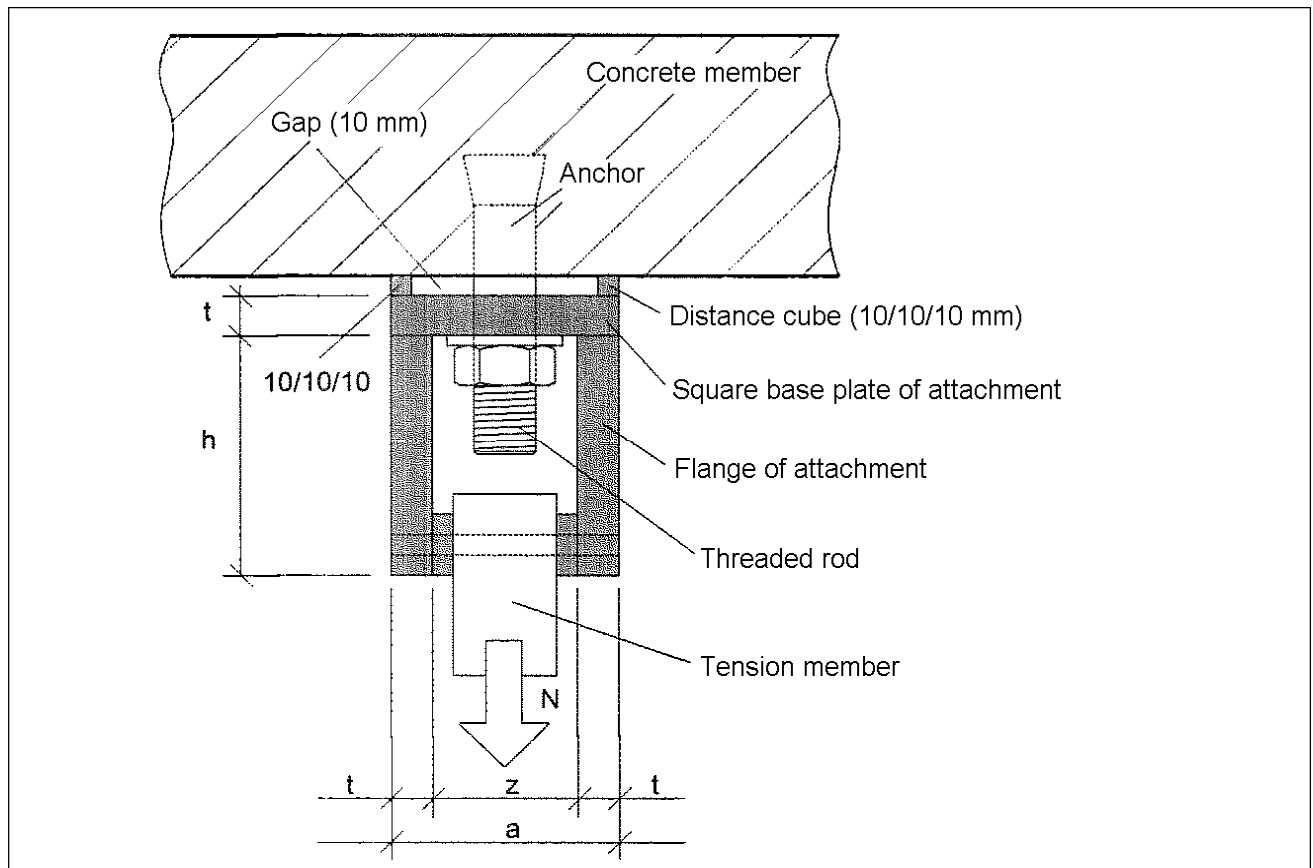


Figure 3.15 Test setup for the determination of the steel failure under fire exposure

The dimensions of fixture have to be chosen depending on the load categories according to Table 3.2. The fixture has to provide a steel stress of $2 - 4 \text{ N/mm}^2$ in the relevant parts. Ordinary punched hole tapes can be used for the tests up to a load of 1,0 kN.

For fasteners with sleeve:

Fastening screws of the minimum strength acc. to the specifications given in the ETA should be used. It is proven by experience that failure of nuts on threaded rods is decisive and should be used for the tests. If commercial standard screws or rods are allowed in the ETA, they should not be delivered by the manufacturer.

Table 3.2 Dimensions of the fixture during the test under fire exposure

Type of adapter	Load categories	Length of the square base plate	flange height/width	profile thickness	distance between the flanges
	$N_{Rk,s,fi}$ [kN]	a [mm]	h / b [mm]	t [mm]	z [mm]
I	$> 1 - \leq 3$	90	100 / 90	15	60
	$> 3 - \leq 5$	90	100 / 90	15	60
II	$> 5 - \leq 7$	110	120 / 110	20	70
	$> 7 - \leq 9$	110	120 / 110	20	70
III	$> 9 - \leq 11$	120	120 / 120	25	70
	$> 11 - \leq 13$	120	120 / 120	25	70

Test procedure:

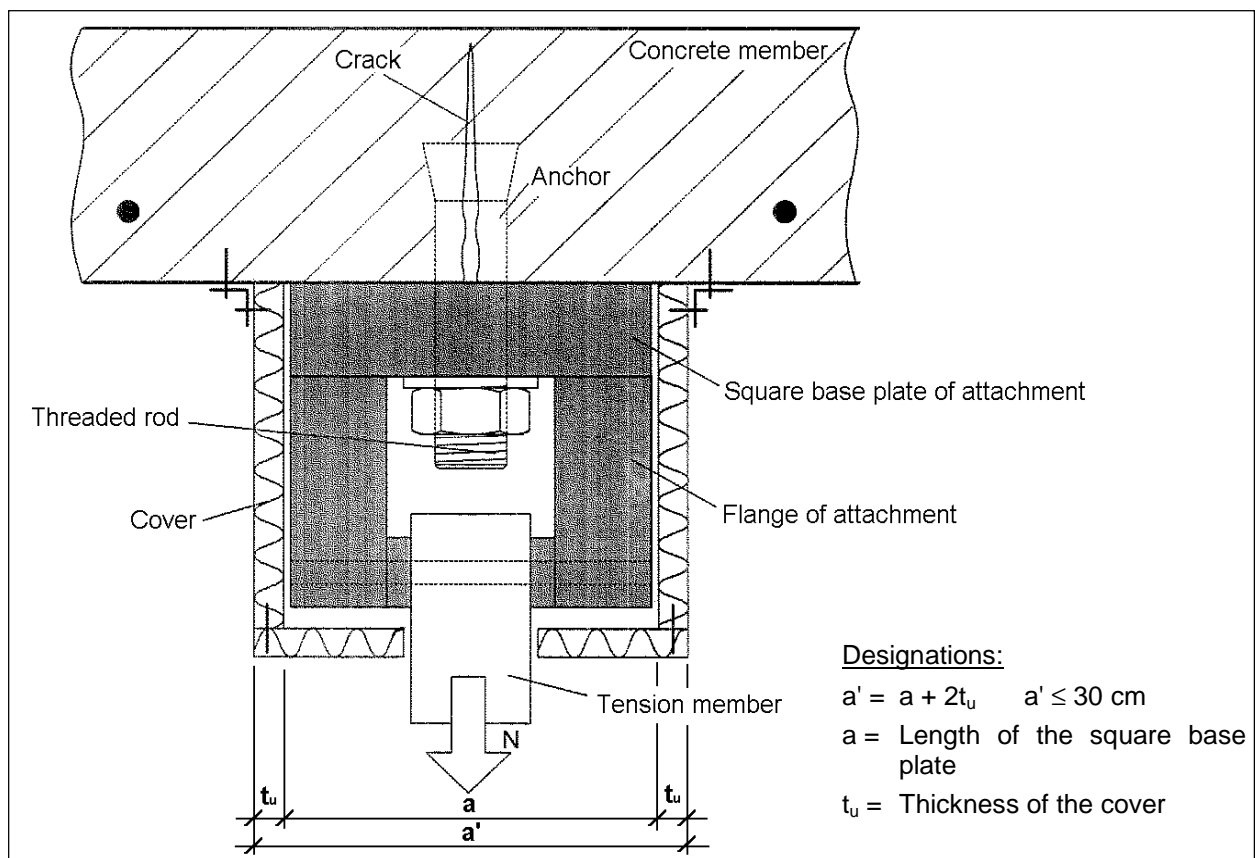
The fastener has to be loaded in tension during the test under fire exposure via the fixture which is defined in Table 3.2. The fire tests have to be carried out according to EN 1363-1:1999 [14] – tests in electric ovens are permitted.

At least 5 tests each using the smallest size d_1 and the medium size d_2 ($\leq M12$) of the fastener have to be carried out. The duration of fire resistance must be more than 60 min in at least 4 tests per fastener size.

For each test record the test load and the corresponding duration to failure.

3.8.2 Tests for pull-out failure under tension load**Test setup:**

The tests have to be carried out in reinforced concrete slabs (C20/25) with an reinforcement of $\phi = 12$ mm / $a = 150$ mm and a degree of reinforcement of $A_s / (b \cdot d)$ of approximately 0,4 %. Steel failure shall not occur. Hence the fixation including the fastener must be lagged or protected. The fixation may be more compact than in the tests according to section 3.8.1. The reinforced concrete slab has to be at least designed for the desired duration of fire resistance. The thickness of the slab shall be $\geq 2 h_{ef}$ and at least be 250 mm. The test set-up can be seen in principle in Figure 3.16.



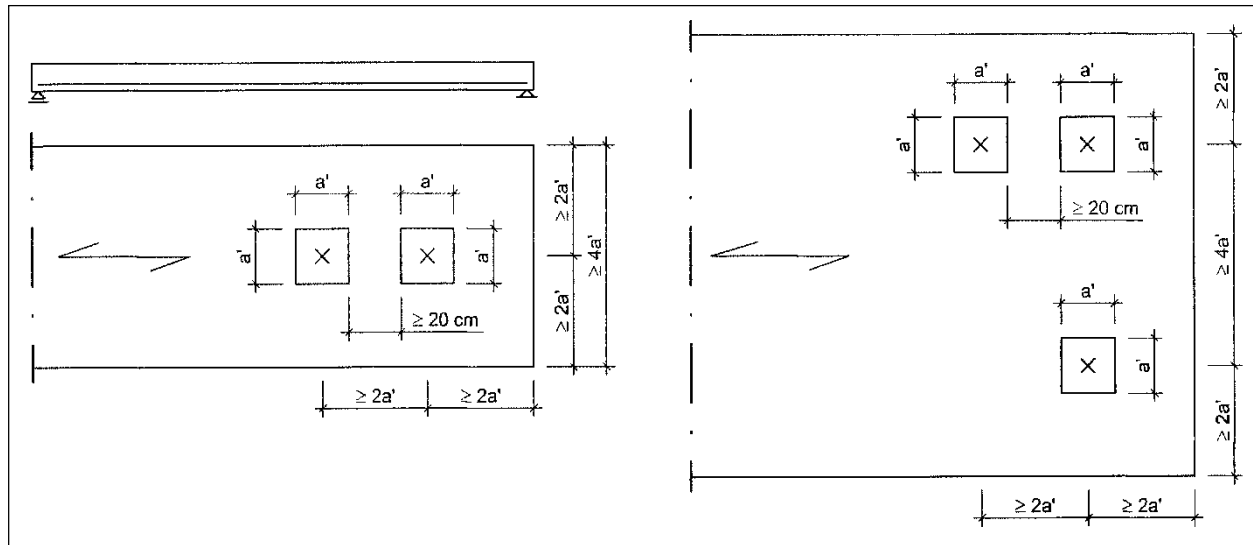


Figure 3.16 Test setup for the determination of the characteristic resistance under fire exposure to pull-out failure

Test procedure:

The reinforced concrete slab must be loaded until cracks appear. The fastener has to be set directly into the crack after the load release. Afterwards the slab has to be loaded again; up to a calculated reinforcement stress of approximately $270 \text{ N/mm}^2 \pm 20 \text{ N/mm}^2$ in the area of the fastener. This will lead to crack widths of approximately 0,10 to 0,25 mm. Next the fastener has to be loaded with the designated load for the fire test according to EN 1363-1:1999 [14]. The steel stress of the reinforcement has to be held constant during the test.

At least 5 tests using fastener with the smallest size, which have an effective embedment depth h_{ef} of approximately 60 mm to 70 mm, have to be carried out for the determination of the limit value curve. The duration of the fire resistance shall be more than 60 min in at least 4 tests.

For each test record the test load and the corresponding duration to failure.

3.8.3 Tests for steel failure under shear load

The test procedure shall be done according to section 3.8.1. The shear load shall be applied via flat-bar steel, which is adequate for a steel stress of 2 to 4 N/mm^2 .

The test set-up can be seen in principle in Figure 3.17.

For each test record the test load and the corresponding duration to failure.

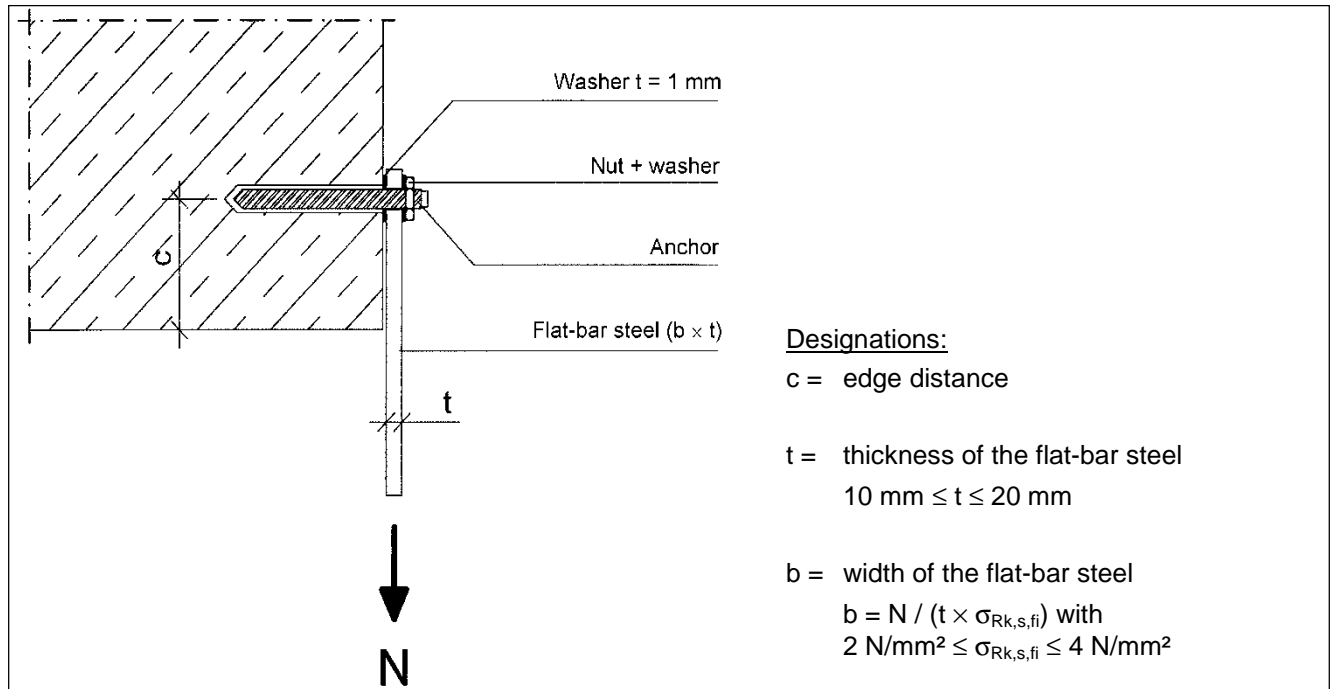
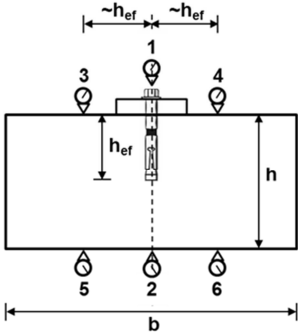


Figure 3.17 Test setup for the determination of the characteristic resistance under fire exposure to steel failure due to shear loads

4 TEST REPORT

Since only relevant parameter shall be followed for each test series this table is meant as a check list. The test report shall include the appropriate information for the particular test series.

1. Description test specimen	
Fastener type	Manufacturer, trade name, dimensions, material
status of specimen	serial product / prototype
production lot / batch	
Steel parts	Mechanical properties (tensile strength, yield limit, fracture elongation), type of coating, e.g. ($f_u = 970 \text{ N/mm}^2$, $R_{p0.2} = 890 \text{ N/mm}^2$, $A_5 = 18\%$, galvanized $5 \mu\text{m}$, functional coating)
Mortar	Designation, size of package, type of cartridge
	xy injection mortar – fast curing version, side by side cartridge xxx ml
	Mass of components, density, viscosity, reactivity, infrared analysis
Type of dispenser and other tools, if any	e.g. Manual dispenser xy, piston plug size xx
2. Test member	
element type / drawing no.	sketch acc. to "examples cross section" and "example for test member with bond breaking pipes"
dimensions	(l / w / h)
concrete mix	e.g. cement, aggregate type and content, w/c-ratio
curing conditions	
age of concrete member at time of testing	
type and grade of reinforcement	
longitudinal reinforcement quantity.	
longitudinal reinforcement size	
pre-debonding length	
type of bond breaker sheets	e.g. wood/ plastic/ metal/ none
reinforcement spacing	e.g. 254 mm horizontal, 50 mm from edges
distribution of reinforcement over depth of member	e.g. two rows, 100 mm from top and bottom
reinforcement is distributed double symmetrically	
3. Setting/ Installation information	
ratio member thickness / h_{nom}	e.g. 2,2
place of fastener installation	formwork side
type/ diameter of support	confined / unconfined $d = 450 \text{ mm}$
spacing between rebar and fastener	200 mm
drilling in hairline crack	yes / no
drill hole prepared separately before each test	yes / no
Drilling method	
Type of drilling machine	
Type and cutting diameter of drill bit	
For stop drills: length of drill bit	
Tools for cleaning of drill holes (if relevant)	
borehole depth h_1 [mm]	
borehole cleaning procedure (if any)	
nominal / effective embedment depth h_{nom}/h_{ef}	
thickness of fixture (t_{fix}) [mm]	
clearance hole d_f [mm]	

installation torque T_{inst} [Nm]	
position of the fastener over load transfer zone in the crack	sketch
verification method of fastener position in crack	e.g. borescope (sketch of crack formation over load transfer zone)
Bonded fasteners only	
type and diameter of cleaning brush	
setting tool/ dispenser	e.g. torque wrench / impact screw driver xy / dispenser xy
curing time	
min / max temperature of concrete over curing time	
height of over-drilled borehole [mm]	e.g. no over-drilling
4. Test parameter	
crack opening mechanism	Describe how the crack width in the area of the load transfer zone is ensured
loading/ unloading rates [sec.]	e.g. 2,5 / 2,5
nominal sustained load	e.g. 10 kN
min. sustained load	10,1 kN
max. sustained load	10,9 kN
mean sustained load	10,3 kN
no. of replicates tested simultaneously	e.g. one
measuring of fastener displacement	e.g. continuously / at the fastener
no. of replicates tested in one specimen/ crack	e.g. 6 per specimen / 2 per crack
amount / type of crack width measurement	e.g. 4 / capacitive sensor
position of the crack width sensors	sketch with distances e.g. : 
determination of crack width at fastener	e.g. (linear interpolation)
Diagram containing: - crack width at the fastener position for the top and bottom of the load transfer zone - plot the cycles in normal logarithmic scale - plot the upper and the lower crack width	
measuring uncertainty for crack width transducers	e.g. $\pm 0,005$ mm.
minimal frequency during the test	
maximal frequency during the test	
5. Test results	
Load at failure	
Load at loss of adhesion	
Displacement at failure	
Displacement at 50% of failure load	
Diagram with load displacement curve	

<p>Failure mode (If initial failure is not clear, a combination of failure modes may be reported.)</p>	<ul style="list-style-type: none"> - (cc) concrete cone failure – give diameter and depth of concrete cone - (sp) splitting– test condition for tests in uncracked concrete in case when a first crack of the concrete is observed - (po) pull-out – pull-out failure may be combined with a shallow concrete breakout - (pt) pull-through– cone being pulled through the expansion sleeve - (s) steel failure– define position of the steel rupture over length of the fastener - (pr) pry-out – concrete breakout opposite to the load direction (may occur for shallow embedment) - (be) bond – element failure - (bbe) bond – borehole failure
<p>Torque at failure (torque tests only)</p>	
<p>Diagram with displacement over time of testing (long term tests only)</p>	

5 REFERENCES

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- [14] EN 1363-1:1999, Fire resistance tests - Part 1: General requirements