# E·OTA

## TECHNICAL REPORT

# Assessment of post-installed rebar connections

TR 023
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**TECHNICAL REPORT FOR POST-INSTALLED REBAR CONNECTIONS**

## INTRODUCTORY NOTES

This Technical Report covers post-installed rebar connections designed in accordance with EN 1992 - 1-1: 2004 (EC2) only. The general basic of this application is ETAG 001, Part 1 and 5. The Technical Report deals with the preconditions, assumptions and the required tests and assessments for post-installed rebars.

Since the application is limited for rebar connections designed in accordance with EC2 many tests which are required for usual bonded anchors (ETAG 001, Part 5) can be omitted because of the followings points:

- The tests will only prove that post-installed rebar connections have a comparable behaviour as cast-in-place rebar connections (comparable load transfer with a comparable load displacement behaviour) under different influences.
- Only tension loads can be transferred as for cast-in-place rebar connections according to EC2, shear loads on the rebars will not be considered.
- Only pull-out or splitting failure occurs, concrete cone failure is avoided by compressing strength and/or large embedment depth.
- Tests in cracked concrete are not required, however, the influence of cracks on the behaviour of post-installed rebar connections is taken into account in the requirements and evaluation of the test results
- Tests for determination of the design concept according to Annex C are not necessary, because only the design concept according EC2 is used.

## 1    SCOPE

### 1.1    General

This Technical Report covers post-installed rebar connections in non-carbonated concrete on the assumption only that the post-installed rebar connections are generally designed in accordance with EC2. The rebar anchoring systems comprises of bonding material and an embedded straight deformed reinforcing bar with properties according to EC2, Annex C; the classes B and C of the rebar are recommended. The bonding material may be manufactured from synthetic mortar, cementitious mortar or a mixture of the two including fillers and/or additives.

The fire resistance of post-installed rebar connections is not covered by this Technical Report.

Fatigue, dynamic or seismic loading of post-installed rebar connections are not covered by this Technical Report.

### 1.2    Intended use

The Technical Report covers applications in non-carbonated concrete C12/15 to C50/60 (EN 206) only, which are also allowed with straight deformed cast-in bars according to (EC2), e.g. those in the following applications:
- an overlapping joint with existing reinforcement in a building component, see Figure 1.1 and 1.2.
- anchoring of the reinforcement at a slab or beam support; end support/bearing of a slab designed as simply supported as well as its reinforcement for restraint forces, see Figure 1.3.
- anchoring of reinforcement of building components stressed primarily in compression, see Fig.1.4
- anchoring of reinforcement to cover the line of acting tensile force, see Figure 1.5
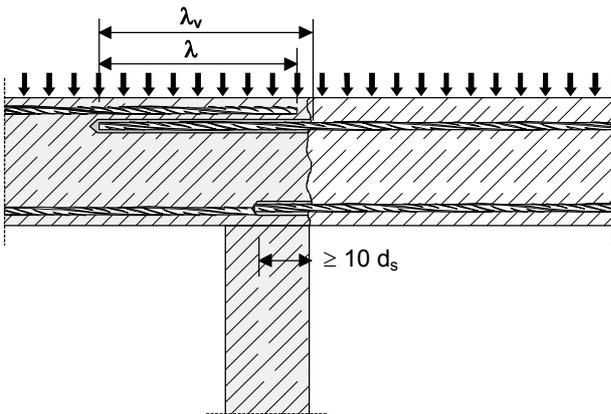
**Figure 1.1:** Overlap joint for rebar connections of slabs and beams
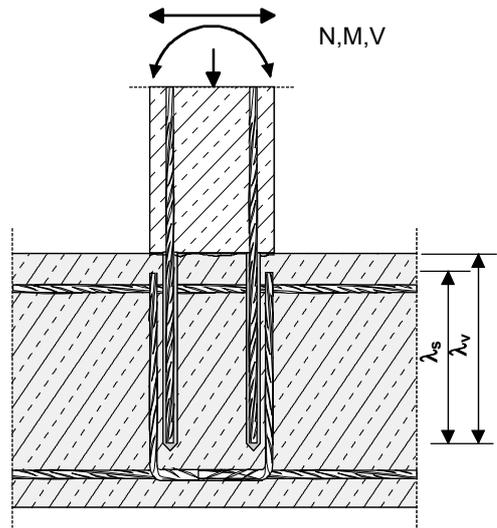


**Figure 1.2:** Overlap joint at a foundation of a column or wall where the rebars are stressed in tension
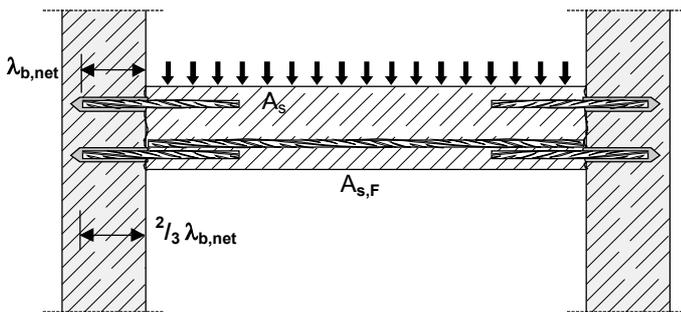


**Figure 1.3:** End anchoring of slabs or beams, designed as simply supported
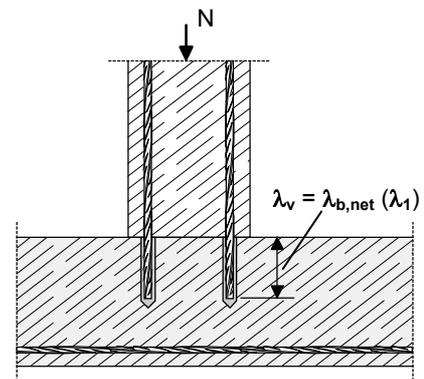


**Figure 1.4:** Rebar connection for components stressed primarily in compression. The rebars are stressed in compression
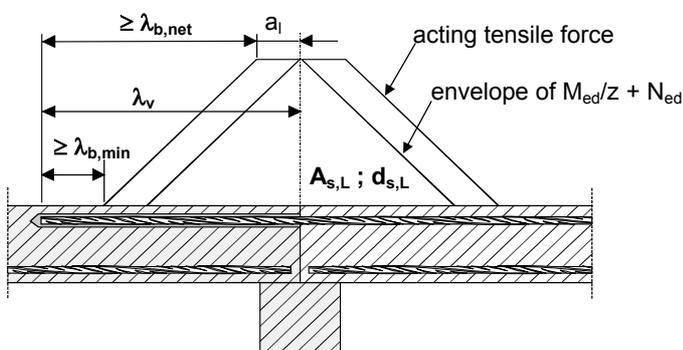


**Figure 1.5:** Anchoring of reinforcement to cover the line of acting tensile force

**Note to Figure 1.1 to 1.5:**

In the Figures no transverse reinforcement is plotted, the transverse reinforcement as required by EC 2 shall be present.

The shear transfer between old and new concrete shall be designed according to EC 2.

### 1.3    Categories

According to EN 206-1 the allowable chloride content in concrete is limited to 0.20 % (Cl 0,20) or to 0.40 %  (Cl 0,40) related to cement content. Regarding these classes the following use categories are established

Use category 1:       post-installed rebar connections in concrete Cl 0,20

Use category 2:       post-installed rebar connections in concrete Cl 0,40


## 2        METHODS OF VERIFICATION

### 2.1    General

The required test programme for post-installed rebar connections is described in Table 2.1 as an overview.

All tests in line 1 to 7 shall be performed as confined tension tests (see ETAG 001, Part 5, Figure 5.2). The dimensions of the members should be chosen such that splitting of the concrete is avoided.

The tests are done with deformed rebars with properties according to Annex C of EC2 with $f_{yk} \geq$ 500 N/mm² and a related rib area $f_R$ between 0.05 and 0.10 in non-cracked concrete C20/25 and C50/60.

In all tests the holes are drilled with the diameter $d_{cut,m}$ according to the specifications of the manufacturer. In general the holes are cleaned according to the written installation instructions of the manufacturer with the cleaning equipment specified by the manufacturer. Exceptions see installation safety tests according to line 3 and 4. The bonding material and the rebars are installed according to the manufacturers' installation instruction with the equipment supplied by the manufacturer.
Installation in flooded holes is not covered by this Technical Report.

The tests shall be done using each drilling method applied for by the manufacturer. However, if the tests are done using hammer drilling, the results of the tests can also be used for compressed air drilling.

**Table 2.1 Tests for post-installed rebar connections**

| | Purpose of test | Concrete (1) | Rebar (2) size | length (9) | Minimum number of tests | Criteria req. $\alpha$ (3) | Test procedure |
|---|---|---|---|---|---|---|---|
| 1 | Bond resistance in C20/25 | C20/25 | 12mm 25mm $d_{max}$ | $10d_s$ $10d_s$ $10d_s$ | 5 5 (4) 5 | see 3.3.2 | 2.2 |
| 2 | Bond resistance in C50/60 | C50/60 | $d_{max}$ | $7d_s$ | 5 | see 3.3.2 | 2.3 |
| 3 | Installation safety dry concrete | C20/25 | $d_{max}$ (5) | $10d_s$ | 5 | $\geq 0.8$ (6) | 2.4 |
| 4 | Installation safety wet concrete | C20/25 | $d_{max}$ (5) | $10d_s$ | 5 | $\geq 0.75$ (6) | 2.5 |
| 5 | Functioning under sustained loads | C20/25 | 12mm | $10d_s$ | 5 | $\geq 0.9$ | 2.6 |
| 6 | Functioning under freeze/thaw conditions | C50/60 (7) | 12mm | $7d_s$ | 5 | $\geq 0.9$ | 2.7 |
| 7 | Functioning with installation direction | C20/25 | $d_{max}$ | $10d_s$ | 5 | $\geq 0.9$ | 2.8 |
| 8 | Installation at maximum embedment depth | C20/25 | $d_{max}$ | max $l_v$ | 5 | see 3.2.3 | 2.9 |
| 9 | Correct injection | | $d_{max}$ | max $l_v$ | 5 | see 3.2.4 | 2.10 |
| 10 | Checking durability of mortar (8) | C20/25 | 12mm | $10d_s$ | 3 x 10 | see 3.3.3 | 2.11 |
| 11 | Corrosion resistance of rebar (10) | C20/25 | 12mm | 70mm | 3 | see 3.3.4.3 | 3.3.4.2 |

Notes to Table 2.1
(1)    All tests performed in non-cracked concrete
(2)    size: diameter of the rebar; $d_{max}$: max. diameter of the rebar specified by the manufacturer; length: embedment length of the bar in the concrete
(3)    see 3.3.1.
(4)    Tests are necessary only, if tests according to line 3 and 4 are done with $d_s = 25mm < d_{max}$
(5)    Tests shall be done with $d_s = 25mm$, if comparison tests according to line 1 are carried out with $d_s = 25mm$ instead of $d_{max}$
(6)    The required $\alpha$ shall not be changed, because the concept of installation safety factor $\gamma_2$ is not supported by EC2.
(7)    The test result shall be normalised to C20/25 by using a factor reflecting the influence of concrete strength or bond resistance as established by tests according to line 1 and 2
(8)    Tests are not required for mortars based on cement only
(9)    $10\,d_s$ and $7\,d_s$ shall be reduced in case of steel failure mode. It is the objective of these tests to determine bond resistance.
(10)    No prove of the corrosion resistance of the rebar is needed if post-installed rebars are used in building components in dry surroundings according to exposure class X0 and XC1 of EC2. Also no prove is needed when only corrosion resistant rebars are specified for all applications; see 3.3.4.1.

## 2.2    Tests for bond resistance in C20/25

The tests shall be performed under normal conditions in concrete C20/25 with an embedment length of the bar of $10d_s$.

## 2.3    Tests for bond resistance in C50/60

The tests shall be performed under normal conditions in concrete C50/60 with an embedment length of the bar of $7d_s$.

## 2.4    Installation safety tests in dry concrete

The tests shall be performed in concrete C20/25 with an embedment length of the bar of $10d_s$, the bar diameter shall be chosen in accordance with notes 4 and 5 of Table 2.1. The following cleaning process of the hole (compare the conditions to ETAG 001, Part 5, 5.1.2.1(a)) has to be carried out in the tests.

Clean the hole with the equipment supplied by the manufacturer, using two blowing by hand pump or compressed air and one brushing operations. The type of blowing and the order of brushing/blowing shall be done as prescribed in the manufacturer's installation instructions. This test procedure is valid only if the manufacturer's installation instructions specify hole cleaning with at least four blowing and two brushing operations. If the instructions specify less than this, then the above requirement (2 blows + 1 brush) shall be reduced proportionately and the number of blows/brushes shall be lowered to the next whole number. Therefore where the manufacturer's installation instructions recommend two blowing and one brushing operations, the suitability tests shall be carried out without the brushing operation and one blowing only.
If precise instructions for hole cleaning are not provided by the manufacturer's installation instructions, then the tests are carried out without hole cleaning.

Install the bonding material and the rebar in accordance with the manufacturer's installation instructions with the equipment supplied by the manufacturer.

## 2.5    Installation safety tests in wet concrete

The tests shall be performed in concrete C20/25 with an embedment length of the bar of $10d_s$, the bar diameter shall be chosen in accordance with notes 4 and 5 of Table 2.1.

Hole cleaning and installation according to 2.4. However the concrete in the area of anchorage must be water saturated when the hole is drilled, cleaned and the rebar is installed, (compare ETAG 001, Part 5, 5.1.2.1(b)).

## 2.6    Functioning under sustained loads and influence of temperature

The performance of the post-installed rebar shall not be adversely affected by short term temperatures within the service temperature range or by long term temperatures up to the maximum long term temperature. For post-installed rebar the service temperature range (a) or (b) according to ETAG 001, Part 5, 4.1.1.2 is specified by the manufacturer.

Range (a):    maxT = 40°C  $\Rightarrow$    Test at maximum long term temperature (T = 20°C)
Range (b)::    maxT = 80°C  $\Rightarrow$    Test at maximum long term temperature (T = 50°C)

The test procedure is taken from ETAG 001, Part 5, 5.1.2.5; with an embedment length of the bar of $10d_s$ and a diameter 12 mm of the rebar.
Install rebar at normal ambient temperature. For both options the constant load $N_{sust}$ shall be

$$N_{sust.} = 0.55 \bullet f_{bm,(line1)}^{t} \bullet \pi \bullet d \bullet l_v \bullet (f_{c,test}/f_{ck})^{0,5} \tag{2.1}$$

$f_{bm,(line1)}^{t}$ = average bond resistance in C20/25 according to Equation (3.3)

$\qquad \leq 10$ N/mm²

$f_{c,test}$ = concrete compression strength of test member

$f_{ck}$ = characteristic concrete compression strength for C20/25

For range (a) maintain load at $N_{sust}$ and maintain temperature at normal ambient temperature (T = 20°C) and measure the displacements until they appear to have stabilized, but at least for three months. The details of the test procedure are taken from ETAG 001, Part 5, 5.1.2.5.

For range (b) raise the temperature of the test chamber to 50°C at a rate of approximately 20°C per hour. Maintain load at $N_{sust}$ and maintain temperature at 50°C and measure the displacements until they appear to have stabilized, but at least for three months. The details of the tests procedure are taken from ETAG 001, Part 5, 5.1.2.5.

To check the remaining load capacity after the sustained load test, unload the rebar and carry out a confined tension test at maximum long term temperature.

## 2.7 Functioning under freeze/thaw conditions

The tests are performed in non-cracked freeze-thaw resistant concrete C50/60 in accordance with ETAG 001, Part 5, 5.1.2.7, with an embedment length of the bar of $7d_s$ and a diameter 12 mm of the rebar.

The sustained load $N_{sust}$ for the tests shall be determined according to the following Equation (2.2).

$$N_{sust.} = 0.4 \bullet f_{bm,(line2)}^{t} \bullet \pi \bullet d \bullet l_v \bullet (f_{c,test}/f_{ck})^{0,5} \tag{2.2}$$

$f_{bm,(line2)}^{t}$ = average bond strength in C50/60 according to Equation (3.3)

$\qquad \leq 18$ N/mm²

$f_{c,test}$ = concrete compression strength of test member

$f_{ck}$ = characteristic concrete compression strength for C50/60

To check the remaining load capacity after the test under freeze/thaw conditions, unload the rebar and carry out a confined tension test at normal ambient temperature.

## 2.8 Functioning with installation direction

If the manufacturer allows in the written installation instructions all installation directions than tension tests are needed with anchor installed vertically upwards only. If the manufacturer allows horizontal and vertical downward only, installation tests have to be done with anchors installed in horizontal direction.

The tests have to be performed with the maximum diameter of the rebar applied for with a length of $10d_s$.

## 2.9 Installation at maximum embedment depth

In the test it is checked that whether a rebar with the maximum embedment depth can be installed correctly with the installation tools defined in the written installation instructions. The tests are done with the maximum rebar diameter and the maximum embedment depth applied for. If during installation significant splitting forces are created (e.g. with capsule type systems where the rebar hammered in), tests shall be done with minimum concrete cover. Concrete, rebar and mortar are heated to the maximum installation ambient temperature specified by the manufacturer. The rebar is installed according to the manufacturers' installation instructions. The tests shall be done for each injection tool specified by the manufacturer.

## 2.10 Correct injection

In the test it is checked that whether the injection of the mortar can be done properly without voids. The injection tests are performed at the lowest installation temperature in acryl tubes with an inner diameter similar to the drilling diameter. The tests are done in horizontal direction with the maximum rebar diameter and the maximum embedment depth applied for. During the injection of the mortar the tube shall be covered so that the installer cannot see the flow of the injection mortar. After the injection of the tube to the required depth, the bar is installed.

## 2.11 Checking durability of mortar (mortar containing resin; including hybrid systems)

To check the chemical resistance of the mortar (mortar containing resin) of the post-installed rebars the so called "slice tests" have to be performed in accordance with ETAG 001, Part 5, 5.1.4 for mortar which contains resin.
The tests are done with the rebar diameter of 12mm and the embedment depth of the bar of 10 $d_s$; the tests may also be performed with a threaded rod.

At least 10 tests shall be taken for every environmental exposure and for comparison; results with splitting failure shall be ignored.

# 3    ASSESSING AND JUDGING THE FITNESS OF ANCHORS FOR AN INTENDED USE

## 3.1    General

In general it shall be shown by the tests according to Table 2.1 that the post-installed rebar system can develop the same design values of bond resistance with the same safety margin as cast-in-place rebars according to EC 2. In EC 2 no requirements for testing are given, but the values for $f_{bd}$ are published. They are given in Table 3.1. These values are valid for worst case conditions, minimum concrete cover, minimum spacing and minimum transverse reinforcement. The tests are done with single rebar with large concrete cover because the influence of the concrete confinement on bond strength is almost the same for cast-in-place and post-installed rebars.

In Table 3.1 a comparison is given, which bond resistance $f_{bm}^{req}$ in tests according to Table 2.1 and an evaluation according to this chapter have to be reached to show equivalence with the values $f_{bd}$. $f_{bm}^{req}$ is based on large number of tests with cast-in-place rebars following the test regime of Table 2.1, line 1 and 2 and using concrete mixed according ETAG 001, Part 1, Annex A.

**Table 3.1 Required bond resistance**

| Concrete strength class (1) | Design values of the ultimate bond resistance according to EC2 for good bond conditions $f_{bd}$ (N/mm²) (2) | Required bond resistance for post-installed rebars $f_{bm}^{req}$ (N/mm²) |
|---|---|---|
| C12/15 | 1,6 | 7,1 |
| C16/20 | 2,0 | 8,6 |
| **C20/25** | **2,3** | **10,0** |
| C25/30 | 2,7 | 11,6 |
| C30/37 | 3,0 | 13,1 |
| C35/45 | 3,4 | 14,5 |
| C40/50 | 3,7 | 15,9 |
| C45/55 | 4,0 | 17,2 |
| **C50/60** | **4,3** | **18,4** |

Note to Table 3.1

(1)    Possible deviations between $f_{bd}$ and concrete strength classes are described in 3.3.2

(2)    $f_{bd}$ = 2.25 $\eta_1$ $\eta_2$ $f_{ctd}$    (according to EC2)

with    $f_{ctd}$ = $\alpha_{ct}$ $f_{ctk,0,05}$ / $\gamma_c$

$\alpha_{ct}$ = 1
$\gamma_c$ = 1.5
$\eta_1$ = 1,0 (good bond conditions)
$\eta_2$ = 1,0 (for $\varnothing \leq 32mm$)

### 3.2 Criteria valid for the tests

### 3.2.1 General

The coefficient of variation of the failure load in the tests according to Table 2.1, line 1 to 7 shall be $\leq 15\%$

### 3.2.1 Functioning under sustained loads and influence of temperature

During the sustained load tests the displacement increase should stabilise and the criteria of the sustained load tests according to ETAG 001, Part 5, 6.1.1.2 shall be fulfilled.

In the tension tests after the sustained loading the average bond resistance shall be determined and the req.$\alpha$ has to be considered according 3.3.

### 3.2.2 Functioning under freeze/thaw conditions

During the freeze/thaw tests the rate of displacement increase shall reduce with increasing number of freeze/thaw cycles to the value almost equal to zero.

In the tension tests after the freeze/thaw conditions the average bond resistance shall be determined and the req.$\alpha$ has to be considered according 3.3.

### 3.2.3 Installation at maximum embedment depth

It shall be possible to install the rebar properly (required embedment depth is reached and the mortar comes out of the hole).

### 3.2.4 Correct injection

The mortar shall fill completely the gap between rebar and hole of the tube over the entire embedment depth. Small voids are usually unavoidable; however, the size and number of these voids should be such that they do not adversely affect the hardening and the bond strength of the mortar and the corrosion resistance. Sagging of the rebar in the fresh mortar immediately after placing and adjustment should be checked; significant sagging may not occur.

### 3.3    Assessment

### 3.3.1   Determination of the bond resistance

**a)** From the results of the tension tests (Table 2.1, line 1 to 7) the average bond resistance is calculated according to Equation (3.1).

$$f_{bm}^t \quad = \quad \frac{N_{u,m}}{\pi \cdot d \cdot l_v} \cdot \left(\frac{0,08}{f_R}\right)^{0,4} \qquad\qquad (3.1)$$

with:

| | | |
|---|---|---|
| $f_{bm}^t$ | = | average bond resistance in the test series |
| $N_{u,m}$ | = | average value of the failure loads $N_{u(fc)}$ in the test series |
| d | = | rebar diameter |
| $l_v$ | = | embedment length of the bar in the concrete |
| $f_R$ | = | related rib area of the tested rebars |
| $N_{u(fc)}$ | = | failure (peak) load of an individual test |

converted to C20/25 (tests Table 2.1, line 1,3,4,5,6,7) or C50/60 (tests Table 2.1, line 2) according to ETAG 001, Part 1, Equation (6.0a). For tests according to Table 2.1 line 6 see note (7) of Table 2.1.

*Comment:*
*If peak load is reached at a displacement $\delta \leq \delta_1$, then use peak load as failure load.*
*If peak load is reached at a displacement load at $\delta > \delta_1$, then use load at $\delta_1$ as failure load.*

*determine of $\delta_1$*

| $d_s$ (mm) | $\delta_1$ (mm) |
|---|---|
| < 25 | 1,5 |
| 25 to 40 | 2,0 |
| > 40 | 3,0 |

**b)** The value $\alpha$ of the tests Table 2.1, line 3 to 7 shall be calculated as follows:

$$\alpha \quad = \quad f_{bm,(line3,4,5,6,7)}^t \;/\; f_{bm,(line1)}^t \qquad\qquad (3.2)$$

with:

$f_{bm,(line3,4,5,6,7)}^t$ = average bond resistance in test series corresponding Table 2.1, line 3,4,5,6 or 7 calculated according to Equation (3.1)

$f_{bm,(line1)}^t$ = average bond resistance in test series corresponding Table 2.1, line 1 calculated according to Equation (3.1)

The calculation of $\alpha$ according to Equation (3.2) should be done with the results of tests with the same diameter.

c) The **bond resistance for the assessment** of the post-installed rebar shall be determined according to **Equations (3.3 and 3.4)**.

$$f_{bm}^{C20/25} = f_{bm,(line1)}^{t} \bullet \min \frac{\alpha}{req\alpha} \bullet \min \frac{\alpha_4}{req\alpha_4} \qquad (3.3)$$

$$f_{bm}^{C50/60} = f_{bm,(line2)}^{t} \bullet \min \frac{\alpha}{req\alpha} \bullet \min \frac{\alpha_4}{req\alpha_4} \qquad (3.4)$$

with:

$f_{bm}^{C20/25}$ ; $f_{bm}^{C50/60}$ = average bond resistance for the assessment of the design bond resistance of post-installed rebar in concrete C20/25 and C50/60

$f_{bm,(line1)}^{t}$ ; $f_{bm,(line2)}^{t}$ = average bond resistance in the corresponding test series Table 2.1, line 1 or 2 calculated according to Equation (3.1)

$\min \dfrac{\alpha}{req\alpha}$ = minimum ratio of the tests Table 2.1, line 3 to 7

           = $\leq 1.0$

$\alpha$ = value according to Equation (3.2)

$req\alpha$ = required value of $\alpha$ according to Table 2.1

$\min \dfrac{\alpha_4}{req\alpha_4}$ = minimum ratio of the tests for checking durability, see 3.3.3.1

           = $\leq 1.0$

## 3.3.2  Assessment of the determined bond resistance

This Technical Report covers post-installed rebar connections only where the average bond resistance for $f_{bm}^{C20/25}$ and /or $f_{bm}^{C50/60}$ is $\geq 7,1$ N/mm$^2$.

**(a)**  Design according to EC2 under consideration of all concrete strength classes

If the average bond resistance $f_{bm}^{C20/25}$ determined according to Equation (3.3) and the average bond resistance $f_{bm}^{C50/60}$ determined according to Equation (3.4) reaches at least the required bond resistance $f_{bm}^{req}$ (10 N/mm$^2$ for C20/25 and 18.4 N/mm$^2$ for C50/60) than the post-installed rebar may be designed using the different values of the design values of the ultimate bond stress, $f_{bd}$ for ribbed bars according to EC2 for all concrete strength classes. An example is shown in Figure 3.1.

If the required bond resistance in C20/25 and/or C50/60 is not fulfilled, than the following limitation under (b) for using the design values of the ultimate bond stress shall be considered:
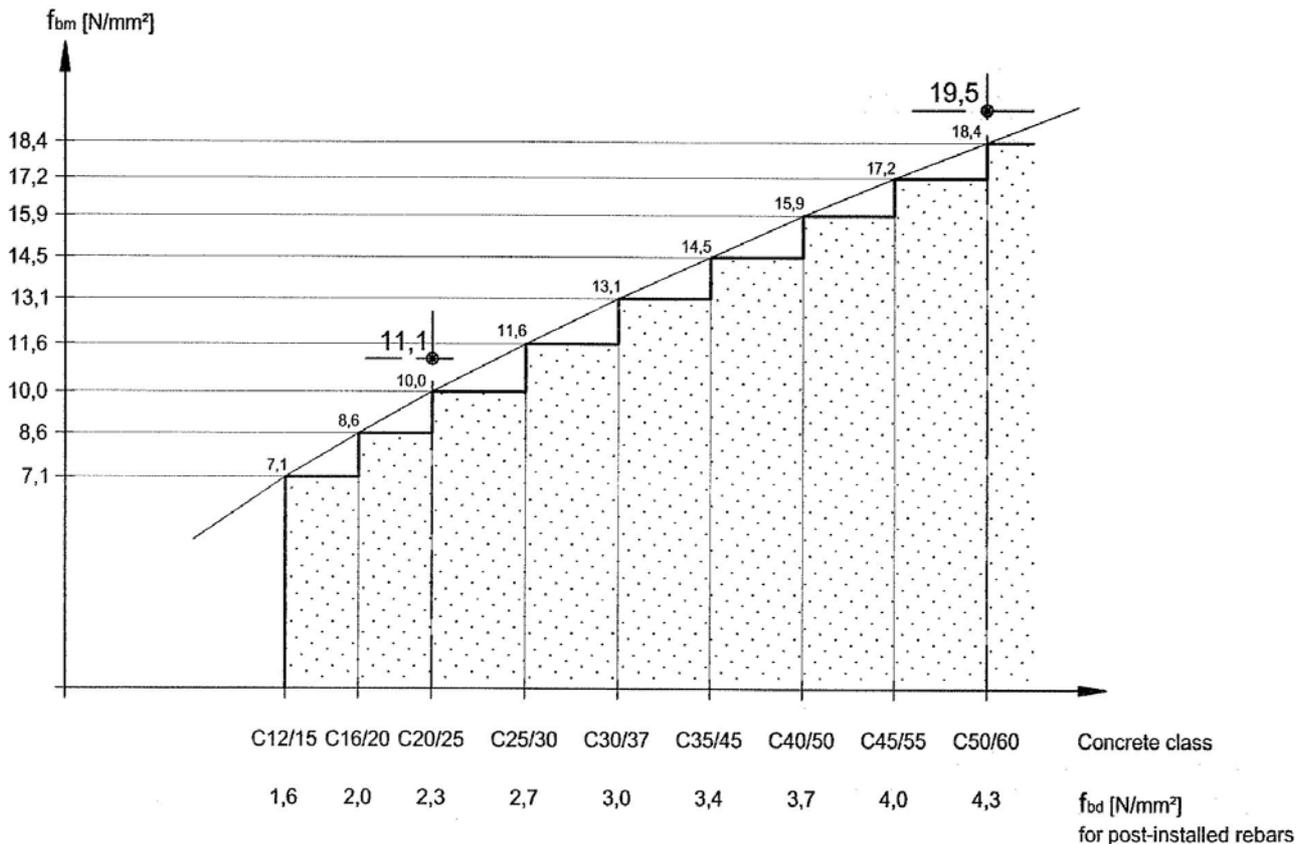
**Figure 3.1:** Design according to EC2 without limitation

**(b)** Design with deviations to EC2

If the required bond resistance in C20/25 and/or C50/60 is not fulfilled, than the following procedure shall be carried out:

- Draw a straight line between the average bond resistances $f_{bm}^{C20/25}$ and $f_{bm}^{C50/60}$
- Draw a step-shaped curve under these line with the given values of EC2 for the different concrete classes so, that this curve does not exceed the straight line.
- The values of the step-shaped curve give the design values of the ultimate bond stress for the post-installed rebar for the different concrete classes. These design values have to be given in the relevant ETA in a table corresponding to the different concrete classes.

It is also possible for the basis of the step-shaped curve to take a bi- or trilinear line instead of a straight line between $f_{bm}^{C20/25}$ and $f_{bm}^{C50/60}$ if there are additional test results of average bond resistance evaluated in the same way as $f_{bm}^{C20/25}$ with intermediate concrete classes.

Example A, see Figure 3.2
Example A shows the determination of the design bond resistance of a post-installed rebar where the average bond resistance $f_{bm}^{C50/60}$ does not reach the required bond resistance for C50/60.

Example B, see Figure 3.3
Example B shows the determination of the design bond resistance of a post-installed rebar where the average bond resistances $f_{bm}^{C20/25}$ and $f_{bm}^{C50/60}$ do not reach the required bond resistances for C20/25 and C50/60.
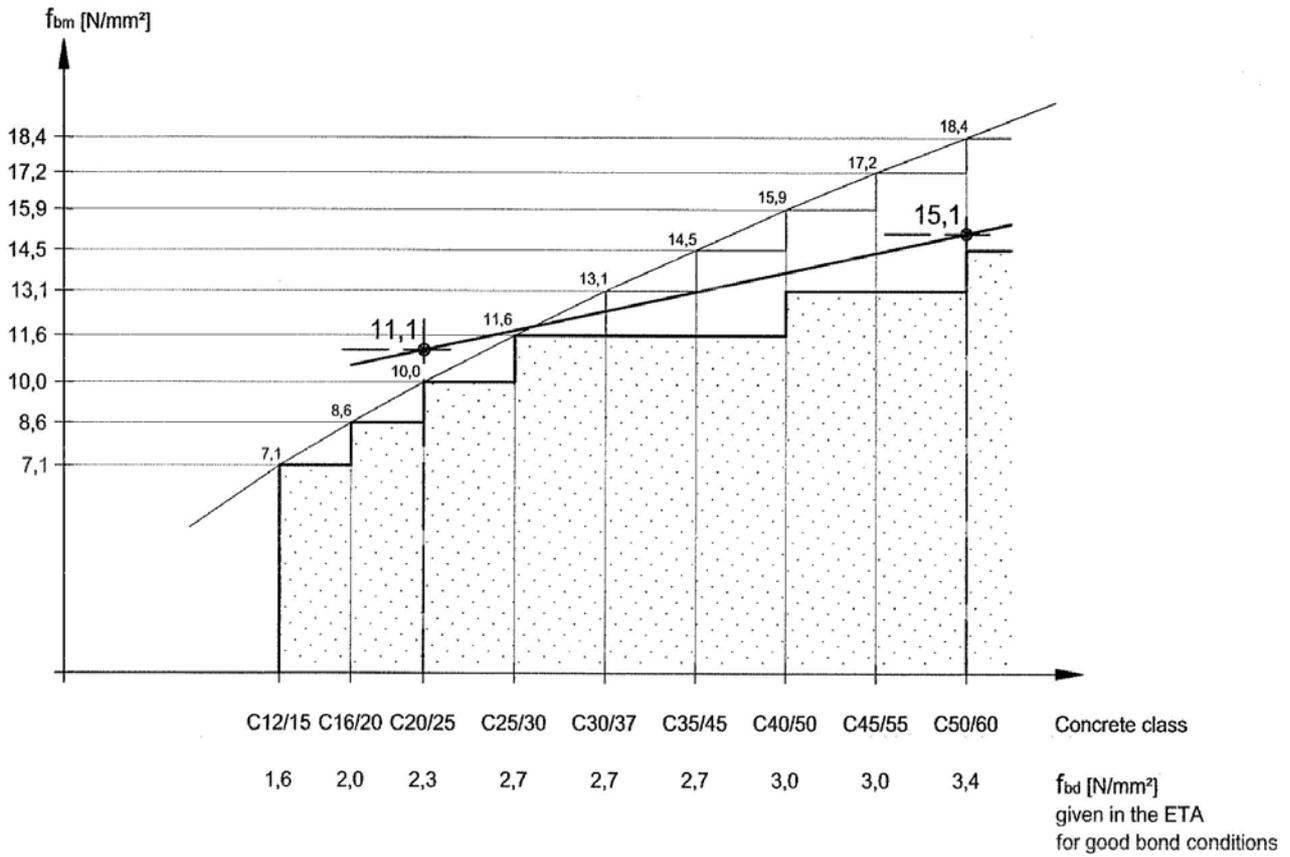
| | C12/15 | C16/20 | C20/25 | C25/30 | C30/37 | C35/45 | C40/50 | C45/55 | C50/60 | Concrete class |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1,6 | 2,0 | 2,3 | 2,7 | 2,7 | 2,7 | 3,0 | 3,0 | 3,4 | $f_{bd}$ [N/mm²] given in the ETA for good bond conditions |

**Figure 3.2:** Example A, design with bond resistance which does not reach the required bond resistance for C50/60



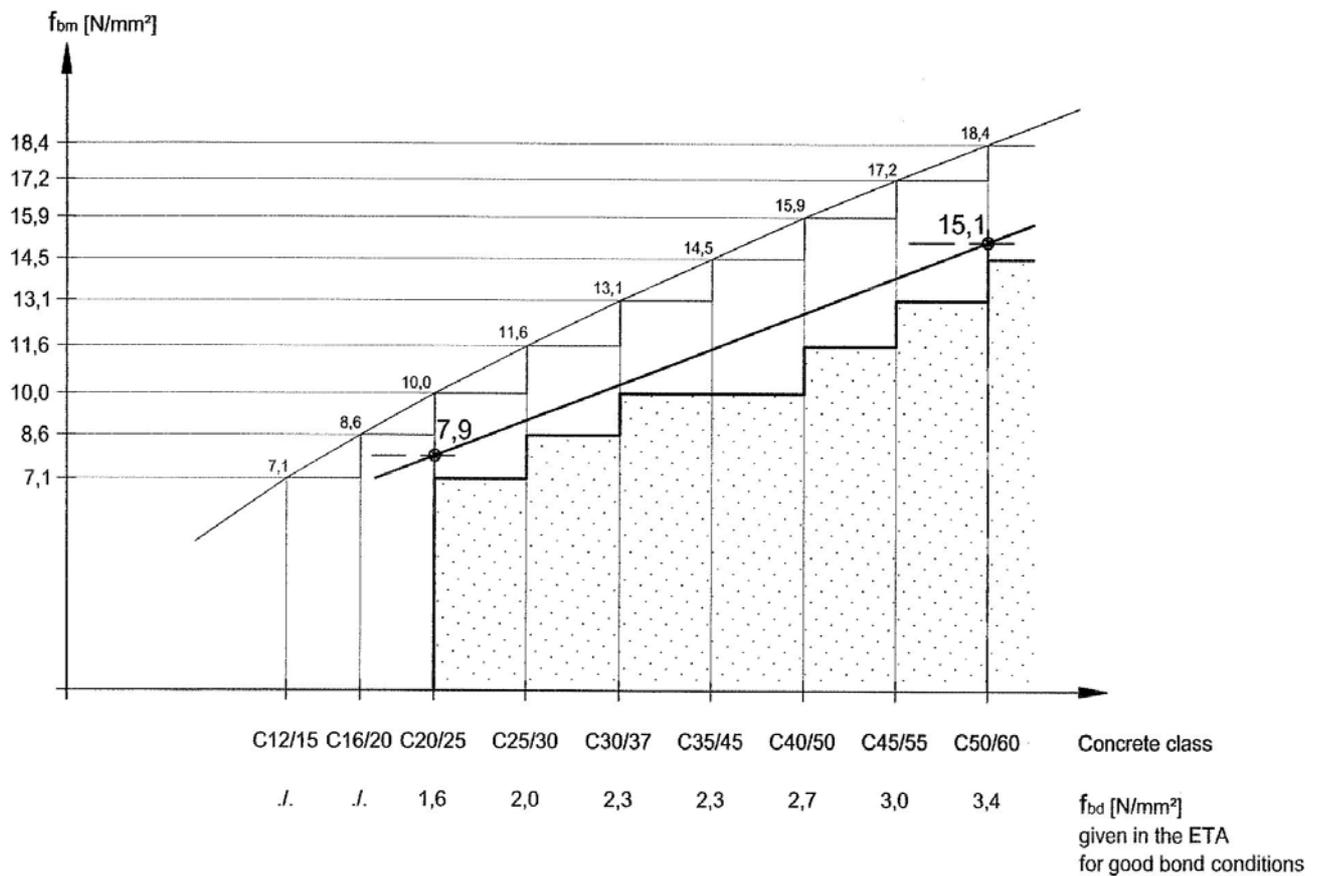| | C12/15 | C16/20 | C20/25 | C25/30 | C30/37 | C35/45 | C40/50 | C45/55 | C50/60 | Concrete class |
|---|---|---|---|---|---|---|---|---|---|---|
| | ./. | ./. | 1,6 | 2,0 | 2,3 | 2,3 | 2,7 | 3,0 | 3,4 | $f_{bd}$ [N/mm²] given in the ETA for good bond conditions |

**Figure 3.3:** Example B, design with bond resistances which do not reach the required bond resistances for C20/25 and C50/60

### 3.3.3  Checking durability of mortar

**3.3.3.1 Mortar containing resin** (including hybrid systems)

In the slice tests it shall be shown that the bond resistance of the slices stored in an alkaline liquid and sulphurous atmosphere media is at least as high as that of the bond resistance of the comparison tests on slices stored under normal conditions. To show compliance with this requirement the factor $\alpha_4$ shall be calculated according to Equation (3.5), compare with ETAG 001, Part 5, 6.1.3.

The factor $\alpha_4$ shall be 1.0 for the tests in alkaline fluid, and 0.9 for the tests in sulphurous atmosphere. If the value $\alpha_4$ is less than the required values then the bond resistance shall be reduced according to 3.3.1, Equation (3.3 and 3.4).

$$\alpha_4 = \frac{\tau_{um(stored)}}{\tau_{um,dry}} \geq req\alpha_4 \qquad\qquad (3.5)$$

$req\alpha_4$ = 1.0 tests in alkaline fluid
= 0.9 tests in sulphurous atmosphere

$\tau_{um(stored)}$ = average bond resistance of the slices stored in alkaline fluid or in sulphurous atmosphere

$\tau_{um,dry}$ = average bond resistance of the comparison tests on slices stored under normal conditions

The bond resistance in the slice tests shall be calculated according to Equation (3.6)

$$\tau_u = \frac{N_u}{\pi \cdot d \cdot h_{sl}} \qquad\qquad (3.6)$$

$N_u$ = measured maximum load
$d$ = diameter of the embedded rebar
$h_{sl}$ = thickness of slice, measured values

**3.3.3.2 Mortar containing cement** (mortar based on cements only)

The durability of the hydraulic binding materials shall be shown.

### 3.3.4  Corrosion resistance of rebar

**3.3.4.1 General**

Cast-in place rebars situated in non-carbonated concrete with limited chloride content according to EN 206-1 are protected by the alkalinity of the concrete, which develops a passive layer on the steel surface, along with the concrete cover.

No prove of the corrosion resistance of the rebar is needed if post-installed rebars are used in building components in dry surroundings according to exposure class X0 and XC1 of EC2. Also no prove is needed when only corrosion resistant rebars are specified for all applications.

-  In all other cases it has to be shown by the following tests that post installed rebar connections provide the same corrosion resistance as cast-in-place rebars.

### 3.3.4.2 Tests

The concrete member is made of C20/25. The mixture and storage is done as described in ETAG 001, Annex A with the following modifications.

- the water/cement ratio is limited to 0.60
- chlorides are added to the mix so that the chloride content of the concrete ( expressed as mass proportion of chloride ions in cement) is 0.20 % for use category 1 and 0.40 % for use category 2

The dimensions are either cubes of 150 mm x 150 mm x 150 mm or prism with a cross section of 150 x 150 mm and an arbitrary length. The age of the concrete cube at installation of the rebars should be at least 21 days. Carbonated surfaces are to be removed.  In minimum 3 rebars with the nominal diameter of 12 mm are to be used. They should be cleaned in such a manner as to ensure no contamination of the rebar with other materials. A suitable method is to degrease with ethanol. They should be ensured to be free from mill scale and other loose contaminants by cleaning methods recommended by the rebar manufacturer.
The installation of the rebar into the concrete is done according to the manufacturers installation instructions for this size. The embedment depth is 70 mm (± 3 mm) and the edge distance is 75 mm. In case of prism the spacing between the rebars is at least 50 mm. The rebar is positioned so as to rest on the bottom of the drilled hole. The top side of the concrete member in the area of the post installed rebar is covered by epoxy resin to prevent carbonation.

After curing of the mortar, the concrete member is immersed into a container filled with artificial tap water (200 mg sodium sulphate and 200 mg sodium bicarbonate dissolved in 1 litre distilled water). By means of distance holder made of plastic, the concrete member is kept at least 1 cm above the bottom of the container. The water level should be 10 mm above the bottom side of the installed rebar. For a height of the concrete member of 150 mm the water line should, therefore, be 90 mm above the bottom side of the concrete member. Each rebar is connected to a cathode with a 100 Ohm resistor (accuracy class ± 1%). The cathodes are L-shaped and made of stainless steel (EN 10088 1.4404, 1.4435 or 1.4539). They are positioned directly on the bottom of the container. The surface of the cathodes in contact to the water is at least 100 $cm^2$. Previous to the test, the cathodes are degreased with ethanol, cleaned by exposing for 10 min in 5% Nitric acid and subsequent rinsing with distilled water. The cathodes have to be stored in the artificial tap water for at least 2 weeks, prior to run the test. The current between the rebar and the cathode is readily determined by measuring the potential drop over the resistor with a micro voltmeter with a resolution of 100 nV and an input resistance of at least 10 MOhm (eg. Keithley M2001).
Additionally, the corrosion potential of each rebar is measured by a Voltmeter with an input resistance of at least 10 MOhm and a resolution of 0.1 mV (e.g. Keithley M2001) against a reference electrode in the container. Ideally, a quasi reference electrode is used. For example, a AgCl coated silver wire immersed in a container filled with a dilute chloride solution (200 mg sodium sulphate, 200 mg sodium bicarbonate and 58 mg sodium chloride dissolved in one litre distilled water) and an opening closed by a diaphragm can be used.

Alternatively an electrolyte bridge can be used to prevent significant pollution of the electrolyte with copper ions or chlorides. Every week the potential of the reference electrode has to be controlled with a saturated Cu/CuSO4 electrode (CSE).The measurement of the current flow and the potential should be done continuously with intervals not greater than 1 hour.

The duration of the tests should be at least 3 month. The measured current flow and the potential are plotted against the duration.
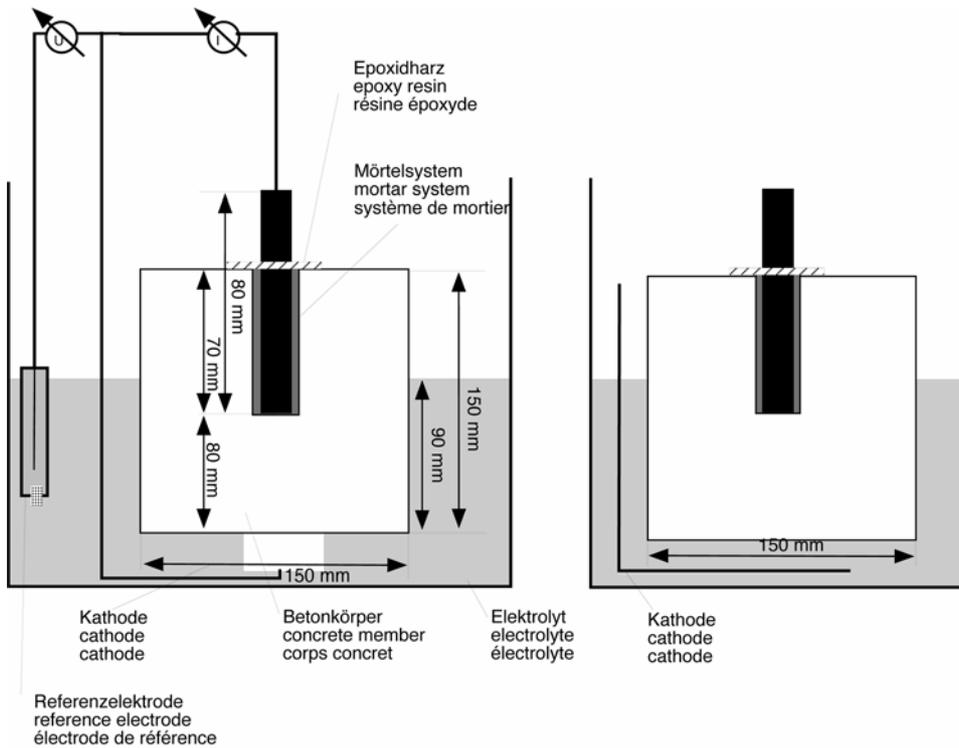
Figure 3.4   Example of test setup in concrete cubes

### 3.3.4.3 Requirements

(a)   During the last third of the testing period the daily mean value of the current shall not exceed 0.28µA and the potential shall not be below –0.2V CSE for all test samples.

(b)   The potential criterion may be omitted if the current criterion of 0.28µA  is fulfilled for all samples and the visual inspection of the rebar after the test does not show any corrosion products.

If either condition (a) or (b) is fulfilled the corrosion resistance of the post installed rebar connection can be judged as being comparable with the corrosion resistance of cast-in-place rebars.

# 4 ASSUMPTIONS UNDER WHICH THE FITNESS FOR USE IS TO BE ASSESSED

## 4.1 Design method for post-installed rebar connections

The post-installed rebar connections assessed according to this Technical Report shall be designed as straight cast-in-place rebars according to EC2 using the values of the design bond resistance $f_{bd}$ for deformed bars according to 3.3.2. The definition of the bond region in EC2 is valid also for post-installed rebars. The conditions in EC2 concerning detailing (e.g. concrete cover in respect to bond and corrosion resistance, bar spacing, transverse reinforcement) shall be complied with. Additional provisions are given in 4.2.
The transfer of shear forces between new and old concrete shall be designed according to EC2.

## 4.2 Additional provisions

To prevent damage of the concrete during drilling the following requirements have to be met:
- Minimum concrete cover:
  $c_{min}$ = 30 + 0,06 $l_v$ $\geq$ 2$d_s$ (mm) for hammer drilled holes
  $c_{min}$ = 50 + 0,08 $l_v$ $\geq$ 2$d_s$ (mm) for compressed air drilled holes

  The factors 0,06 and 0,08 should take into account the possible deviations during the drilling process. This value might be smaller if special drilling aid devices are used.

- Minimum clear spacing between two post-installed bars a = 40 mm $\geq$ 4$d_s$

To account for potentially different behaviour of post-installed and cast-in-place rebars in cracked concrete,
- in general, the minimum anchorages length $l_{b,min}$ and $l_{o,min}$ given in the EC 2 for anchorages and overlap splices shall be increased by a factor of 1.5. This increase may be neglected if it can be shown that the bond strength of the selected post-installed rebars and cast-in-place rebars in cracked concrete (w = 0.3 mm) is similar. In this case the influence of crack openings (crack movement tests) can be neglected because for rebar connections several rebars are present (multiple use) and not all of the rebars will be situated in a longitudinal crack.

*Note: According to test results, the bond resistance of cast-in-place rebars in cracked concrete is about 75% of the value valid for non-cracked concrete. For post-installed rebars it is assumed that the bond resistance in cracked concrete is about 50% of the value in non-cracked concrete. For certain post-installed rebar systems, however, the influence of cracks on the bond resistance may be smaller. Therefore the increase in the minimum bond length for anchorages or overlap splices may be omitted if the following conditions can be demonstrated:*

> *a) a higher resistance of post-installed rebars in non-cracked concrete than required in 3.3 e.g. $f_{bm} > 15$ N/mm² in C20/25.*

> *b) a smaller influence of cracks on the bond resistance of post-installed rebars than assumed above e.g. a reduction factor in cracked concrete of 0.75 instead of 0.5.*

> *c) a combination of both a) and b) e.g. bond resistance of 13 N/mm² together with a reduction factor of 0.6.*

> *The values of the examples are valid for justifying use of the minimum bond length. If these values are not achieved the minimum bond length shall be increased by a factor which may be interpolated linearly between 1.0 and 1.5, in increments of 0.1.*

## 4.3 Recommendations for packaging, transport and storage

The recommendations for packaging, transport and storage should be taken from ETAG 001, Part 5, 7.2.

## 4.4    Preparation of the joints

The surface of the joint between new and existing concrete should be prepared (roughing, keying) according to the envisaged intended use according to EC2.
In case of a connection being made between new and existing concrete where the surface layer of the existing concrete is carbonated, the layer should be removed in the area of the new reinforcing bar (with a diameter $d_s$ + 60mm) prior to the installation of the new bar.

## 4.5    Installation of post-installed rebars

The installation of post-installed rebars shall be carried out according to the manufacturer's installation instructions.

The installation of post-installed rebars shall be done only by suitable trained installer and under supervision on site. The conditions under which an installer may be considered as suitable trained and the conditions for supervision on site are up to the Member State in which the installation is done. The drilling and cleaning of the hole and the installation shall be performed only with the equipment specified by the manufacturer. It shall be ensured that this equipment is available on site and is used.

*Note:*
*In the installation safety tests the sensitivity of post-installed rebars to define installation inaccuracies is checked. A reduction of the bond resistance of up to 25% is allowed compared to installation according to the manufacturer's installation instruction. For bonded anchors this reduction is taken into account by an additional partial safety factor $\gamma_2$. This increase of the safety factor is not in line with the safety concept of EC2. The probability of installation inaccuracies is significantly reduced with suitable trained installer and supervision on site. Therefore higher requirements on the training of the installer and supervision on site than assumed in ETAG 001, Part 5 are necessary to ensure that the manufacturer's installation instructions are strictly complied with. The conditions under which an installer may be considered as suitable trained and the conditions for supervision on site are up to the Member State in which the installation is done.*

# 5    THE ETA CONTENTS

In general ETAG 001, Part 1 and Part 5, 7.3 applies

Furthermore in the ETA the following items should be given:
- Intended use (compare Figures 1.1 to 1.5)
- Table with the design values of the ultimate bond resistance for the different concrete classes
- Any restriction compared to EC2 (see 4.2)
- Preparation of the joints (see 4.4)
- Information about packaging, transport and storage (see 4.3)
- Range of temperature during working life
  a) up to 40°C
  b) up to 80°C
- Minimum and maximum rebar diameter
- Installation instructions:
  Drill hole diameter and gap between rebar and drill hole
  Drilling technique and equipment
  Cleaning technique and equipment
  Mixing technique and equipment
  Injection equipment with corresponding maximum embedment depth
  Complete installation instruction with installation directions
  Minimum and maximum temperature of concrete and mortar during installation and corresponding curing time, (usually 0°C to + 40°C)
   Maximum time for the processing/installation and minimum curing time
- Requirements on suitable trained installer and the conditions for supervision on site.

It is in the responsibility of the manufacturer to ensure that the information on the specific conditions is given to those who are concerned.