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GUIDELINE FOR EUROPEAN TECHNICAL APPROVAL
OF

METAL ANCHORS FOR USE IN CONCRETE

Annex B: TESTS FOR ADMISSIBLE SERVICE CONDITIONS DETAILED INFORMATION

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ANNEX B

TESTS FOR ADMISSIBLE SERVICE CONDITIONS

DETAILED INFORMATION

1 INTRODUCTION

This annex sets out the tests which will be required for the determination of the admissible service conditions. The number of tests depends on the following:

- which Option is chosen by the manufacturer
- the current experience available on the load bearing behaviour of anchors and
- whether or not application of the experience is appropriate.

2 RANGE OF CURRENT EXPERIENCE

2.0 General

In general the following equations for failure loads are valid for single anchors. They are based on current test experience and are used in deriving mean failure loads and 5 %-fractiles in appropriate cases. Where insufficient experience exists to allow a theoretical approach, a note to this effect is included.

The current experience is valid for expansion- and undercut anchors as defined in Part 1, Figure 2.2. a b c. Equations for bonded anchors are listed in Part 5.

The following equations for calculation of the concrete failure loads are based on the compression strength of concrete test members, $f_{c,test}$, measured on cubes with a side length of 200 mm. If the compression strength is measured on cubes with a different side length or on cylinders, they may be converted using the conversion Equations (2.1) of Annex A.

If the mean failure loads $F_{Ru,m}$ and the coefficient of variation, v , are given, in the following the characteristic failure load, F_{Rk} , ,can be calculated by Equation (2.1)

$$F_{Rk} = F_{Ru,m} \cdot (1 - 1{,}645 \cdot \mathrm{v}) \qquad (2.1)$$

2.1 Notation List

The same notations are used as given in the notation lists of Part 1 and Annex C.

2.2 Tension Load

2.2.1 Steel Failure

The average failure load is given by Equation (2.2) and is valid for cracked and non-cracked concrete C20/25 to C50/60.

$$N_{Ru,m} = A_s \cdot f_{u,test} \qquad (2.2)$$

The characteristic failure load may be calculated by using f_{uk} instead of $f_{u,test}$ in Equation (2.2).

2.2.2 Concrete Cone Failure

The average failure load in non-cracked concrete C20/25 to C50/60 is given in Equation (2.3)

$$N_{Ru,m} = 13{,}5 \cdot h_{ef}^{1,5} \cdot f_{c,test}^{0,5} \qquad \mathrm{v} = 15\% \qquad (2.3)$$

The average failure load in cracked concrete C20/25 to C50/60 is given in Equation (2.4)

$$N_{Ru,m} = 9{,}5 \cdot h_{ef}^{1,5} \cdot f_{c,test}^{0,5} \qquad \mathrm{v} = 15\% \qquad (2.4)$$

The distance between anchors required for transferring a load according to Equation (2.3) or Equation (2.4) in cracked or non-cracked concrete C20/25 to C50/60 may be taken as

$$s_{cr,N} = 3 \cdot h_{ef} \quad (2.5)$$

The distance from an edge required for transferring a load according to Equation (2.3) or Equation (2.4) in cracked or non-cracked concrete C20/25 to C50/60 may be taken as

$$c_{cr,N} = 1{,}5 \cdot h_{ef} \quad (2.6)$$

2.2.3 Pull-Out Failure

At present there is no generally valid experience, since the failure load is determined by the individual design of each anchor. It is therefore necessary to derive the characteristic load by testing.

The spacing and edge distance required to transfer the pull-out failure load may conservatively be taken according to Equations (2.5) and (2.6).

2.2.4 Splitting Failure

At present there is no generally valid experience to calculate the failure load in non-cracked concrete C20/25 to C50/60 for this failure mode. As a first indication, the following edge distances for ensuring the failure load according to Equation (2.3) is not reduced, may be chosen:

$$c_{cr,sp} = 2{,}0 \cdot h_{ef} \quad \text{for undercut anchors} \quad (2.7.a)$$

$$c_{cr,sp} = 3{,}0 \cdot h_{ef} \quad \text{for torque-controlled expansion anchors} \quad (2.7.b)$$

$$s_{cr,sp} = 2 \cdot c_{cr,sp} \quad (2.8)$$

In cracked concrete it is assumed that splitting of the concrete will not govern, if the crack width is limited by the reinforcement to $w_k \approx$ 0,3 mm.

2.3 Shear Load

2.3.1 Steel Failure

The average failure load is given by Equation (2.9a) and is valid for cracked and non-cracked concrete C20/25 to C50/60.

$$V_{Ru,m} = 0{,}6 \cdot A_s \cdot f_{u,test} \quad (2.9a)$$

The characteristic failure load may be calculated by Equation (2.9b).

$$V_{Rk} = 0{,}5 \cdot A_s \cdot f_{u,test} \quad (2.9b)$$

2.3.2 Concrete edge failure

The average failure load in non-cracked concrete C20/25 to C50/60 is given in Equation (2.10)

$$V_{Ru,m} = 0{,}90 \cdot d_{nom}^{0,5} \cdot (l_f \,/\, d_{nom})^{0,2} \cdot f_{c,test}^{0,5} \cdot c_1^{1,5} \qquad v = 17\% \quad (2.10)$$

The average failure load in cracked concrete C20/25 to C50/60 is given in Equation (2.11). Because of limited experience a reduction factor of 0,7 in comparison to Equation (2.10) is taken.

$$V_{Ru,m} = 0{,}63 \cdot d_{nom}^{0,5} \cdot (l_f \,/\, d_{nom})^{0,2} \cdot f_{c,test}^{0,5} \cdot c_1^{1,5} \qquad v = 17\% \quad (2.11)$$

Equations (2.10) and (2.11) are valid for concrete member depth $h \geq 1{,}5 \cdot c_1$.

The distance between anchors required for transferring a load according to Equation (2.10) or Equation(2.11) in cracked or non-cracked concrete C20/25 to C50/60 may be taken as

$$s_{cr,V} = 3 \cdot c_1 \qquad (2.12)$$

The distance from an edge perpendicular to the load direction required for transferring a load according to Equation (2.10) or Equation (2.11) in cracked or non-cracked concrete C20/25 to C50/60 may be taken as

$$c_{cr,V} = 1{,}5 \cdot c_1 \qquad (2.13)$$

The spacing s and edge distances c_1 and c_2 should not be smaller than the minimum value in order to prevent splitting of the concrete member while installing the anchor.

2.3.3 Concrete Pryout Failure

The average failure load in non-cracked concrete C20/25 to C50/60 is given in Equation (2.14)

$$V_{Ru,m} = k \cdot N_{Ru,m} \qquad \text{v} = 15\% \qquad (2.14)$$

with $k = 1{,}0$ for $h_{ef} < 60mm$
$k = 2{,}0$ for $h_{ef} \geq 60mm$
$N_{Ru,m}$ see Equation (2.3)

The average failure load in cracked concrete C20/25 to C50/60 is given in Equation (2.15). Because of limited experience a reduction factor of 0,7 in comparison to Equation (2.14) is taken into account by using $N_{Ru,m}$ according to Equation (2.4).

$$V_{Ru,m} = k \cdot N_{Ru,m} \qquad \text{v} = 15\% \qquad (2.15)$$

with $k = 1{,}0$ for $h_{ef} < 60mm$
$k = 2{,}0$ for $h_{ef} \geq 60mm$
$N_{Ru,m}$ see Equation (2.4)

The spacing and edge distances given in 2.2.2 apply. If smaller spacings and edge distances are chosen in the test, the influencing factors $A_{c,N} / A^0_{c,N}$ and $\psi_{s,N}$ on $N_{Ru,m}$ shall be considered according to the design method A in Annex C, 5.2.2.3(b) and (c).

2.4 Combined Tension and Shear Load

2.4.1 Steel Failure

The average failure load is given by Equation (2.16) which is valid for cracked and non-cracked concrete C20/25 to C50/60

$$\left(N_S / N_{Ru,m}\right)^{2,0} + \left(V_S / V_{Ru,m}\right)^{2,0} \geq 1{,}0 \qquad (2.16)$$

with N_S = tension component of the applied load
V_S = shear component of the applied load
$N_{Ru,m}$ according to Equation (2.2)

$V_{Ru,m}$ according to Equation (2.9)

2.4.2 Other Failure Modes

The average failure load is given by Equation (2.17) which is valid for cracked and non-cracked concrete C20/25 to C50/60.

$$\left(N_S / N_{Ru,m}\right)^{1,5} + \left(V_S / V_{Ru,m}\right)^{1,5} \geq 1,0 \qquad (2.17)$$

with N_S = tension component of the applied load

V_s = shear component of the applied load

$N_{Ru,m}$, $V_{Ru,m}$ minimum value of the average failure loads for the different failure modes under tension or shear loads

The following simplified approach may also be used to calculate the average failure load under combined tension and shear load in cracked and non-cracked concrete C20/25 to C50/60 (the equation is not valid for pure tension or shear loads).

$$\left(N_S / N_{Ru,m}\right) + \left(V_S / V_{Ru,m}\right) \geq 1,2 \qquad (2.18)$$

with N_S = tension component of the applied load

V_s = shear component of the applied load

$N_{Ru,m}$, $V_{Ru,m}$ minimum value of the average failure loads for the different failure modes under tension or shear loads

3 TEST PROGRAMME

The test programme is arranged between the approval body and the applicant. In general, test results are available from the manufacturer. If the corresponding test report contains all relevant data (see Annex A, 6) then test results submitted by the manufacturer may be considered (see Part 1, 5.1.3). However, they will only be considered in the assessment if the results are consistent with the Institute's test results or experience.

3.1 Complete Test Programme

The following tables show the test programme required for determining admissible service conditions, for Options 1 to 12, where there are no existing relevant data and therefore does not allow any reduction in testing.

The Option chosen is a matter for the applicant to decide.

In particular, the tables apply where:

- new anchors are claimed to have significantly improved behaviour compared with those to which current experience applies. In particular, if in the case of concrete failure, higher failure loads than given by the relevant equations are looked for, then the corresponding values for the edge distance c_{cr} and spacing s_{cr} shall be assessed as well.

- anchors fail in a mode for which only limited experience exists (eg. pull-out failure).In this case the values for c_{cr} and s_{cr} may be reduced compared to the values given in 2.2 and 2.3 for Option 3 to 6 and 9 to 12.

3.2 Reduced Test Programme

At the applicant's request and if agreed by the approval body, a reduced test programme for anchors based on the assumption that its performance is consistent with current experience may be carried out, providing:

(a) A minimum test programme is used to confirm whether or not the anchor's behaviour, judged according to all the parameters referred to in 2 falls within the range of current experience. Confirmation of the assumption will require an adequate statistical evaluation of the test-data for a confidence level (two sided) of P = 90%.

(b) For comparison of the mean values the t-test should be used. However, the coefficient of variation of one test series should not directly be compared with the coefficient of variation for current experience given in 2. This is due to the fact that the equations for calculating the average failure loads were deduced by using the results of a large number of test series in different concrete members. Therefore the given coefficients of variation include the influence of different concrete mixes and different curing conditions. The coefficient of variation of one test series performed in one concrete member can be significantly smaller than the values given in 2. In this case a normal F-test does not work and it has to be shown by engineering judgement that the coefficient of variation of the test series is inside current experience.

(c) That if the load bearing capacity of the anchors is higher than calculated by the equations and if the coefficient of variation does not exceed current experience the manufacturer then does not ask for improved values but accepts current experience.

The reduction of the number of tests is listed in notes 1 to 5 and 7 to 10 of the following Option tables 1 to 12.

The Tables at the end of the document show the reduced test programme required for determining admissible service conditions, for Options 1 to 12, if the design model of Annex C is used.

3.3 Detailed Information on Options

The number of required tests for the different options is given in the following Option tables. Options 1 to 6 cover anchors for cracked and non-cracked concrete, Options 7 to 12 anchors for non-cracked concrete only. Consequently the test programme for Options 1 to 6 include additional tests in cracked concrete.

Option 12 gives the smallest, Option 1 the largest test programme. Therefore detailed information is given first for Options 12 to 7 and then for Options 6 to 1.

The Tables at the end of the document show the reduced test programme for Options 1 to 12, if the design model of Annex C is used.

Option 12

Goal: Determination of one characteristic load valid for all load directions as well as all concrete strength classes in non-cracked concrete. This characteristic load is valid for a spacing $s \geq s_{cr}$ and an edge distance $c \geq c_{cr}$.

Applicant's choice:
s_{cr}, c_{cr}

Assessment: The characteristic load is the smallest value assessed from the results of the test according to rows 1 to 4. For anchor groups the characteristic resistance of the group has to be divided by the number of anchors of the group. The evaluation shall be done according to Part 1, Chapter 6. The spacing and edge distance shall be chosen such that the requirements given in Part 1, 6.1.2.2.3 for tension loading and the requirements given in Part 1, 6.1.2.2.4 for shear loading are met. The partial safety factor γ_2 shall be assessed according to Part 1, 6.1.2.2.2. Applications with spacing $s < s_{cr}$ and edge distance $c < c_{cr}$ are not allowed.

Design: The anchors shall be designed according to design method C in Annex C.

Option 11

Goal: Determination of one characteristic load valid for all load directions for concrete strength classes C20/25 to C50/60 in non-cracked concrete.

Applicant's choice, assessment and design:
see Option 12.

The spacing s_{cr} and edge distance c_{cr} evaluated for C20/25 are valid for all strength classes C20/25 to C50/60.

Option 10

Goal: Determination of one characteristic load valid for all load directions as well as all concrete strength classes in non-cracked concrete. The characteristic load is valid for a spacing $s \geq s_{cr}$ and an edge distance $c \geq c_{cr}$.
Determination of s_{min} and c_{min} for a reduced characteristic load.

s_{cr} = required distance between anchors for transmission of the characteristic load F_{Rk} under tension, shear or combined tension and shear loading.

s_{min}= minimum distance between anchors to avoid failure mode "splitting"; reduction of F_{Rk} according to design method B in Annex C.

c_{cr} = required edge distance for transmission of the characteristic load F_{Rk} under tension, shear or combined tension and shear loading.

c_{min}= minimum edge distance to avoid failure mode "splitting", reduction of F_{Rk} according to design method B in Annex C.

Applicant's choice:
s_{cr} and c_{cr}, s_{min} and c_{min}

Assessment: Calculation of the characteristic load from the results of the test according to row 1 taking into account Part 1,6.1.2.2.1. For the tension test according to row 2 and 3 the characteristic spacing s_{cr} and edge distance c_{cr} is evaluated according to Part 1, 6.1.2.2.3.
The edge distance c_1 in the shear tests of row 4 shall be chosen such that the characteristic failure load for one anchor is at least as high as the above mentioned value evaluated from the tests of row 1.
The results of test according to row 5 shall fulfil the conditions given in Part 1, 6.1.2.2.5.
The partial safety factor γ_2 shall be assessed according to Part 1, 6.1.2.2.2.
It should be noted that the characteristic edge distance c_{cr} = 0.5 s_{cr} may be larger for shear loading than for tension loading, if the characteristic load is calculated from the tension tests. Therefore, if for a characteristic edge distance c_{cr} and characteristic spacing s_{cr} the values valid for tension loading are chosen, then the characteristic load may be reduced compared to the value possible for tension loading.

Design: Anchors tested by this Option shall be designed according to the design method B in Annex C.

Option 9

Goal: Determination of one characteristic load valid for all load directions for concrete strength classes C20/25 to C50/60 in non-cracked concrete.

Applicant's choice, assessment and design:
see Option 10.

The spacings s_{cr}, s_{min} and edge distances c_{cr} and c_{min} evaluated for C20/25 are valid for all concrete strength classes C20/25 to C 50/60.

Option 8

Goal: Determination of different characteristic loads for different load directions and different failure modes which are valid for all concrete strength classes in non-cracked concrete. The spacing $s_{cr,N}$ and edge distance $c_{cr,N}$ are valid for the characteristic resistances of the anchor under tension loading as well as under shear loading with pryout failure. The characteristic shear resistance for anchors near an edge is evaluated as a function of the edge distance c_1. The spacing $s_{cr,V}$ and edge distance $c_{2cr,V}$ for shear loading and concrete failure mode is determined by tests.
Also s_{min} and c_{min} for all failure modes and for a reduced characteristic load are determined.

Applicant´s choise:
$s_{cr,N}$ and $c_{cr,N}$ for tension load, $s_{cr,V}$ and $c_{cr,V}$ for shear load, s_{min} and c_{min}

Assessment: Calculation of the characteristic resistance for all load directions from the results of the test according to row 1 according to Part 1,6.1.2.2.1. The spacing $s_{cr,N}$ and edge distance $c_{cr,N}$ are evaluated according to Part 1, 6.1.2.2.3. The characteristic resistance for shear loading near an edge c_1 and the spacing $s_{cr,V}$ and edge distance $c_{cr,V}$ are assessed according to Part 1, 6.1.2.2.4. The results of test according to row 5 shall fulfil the conditions given in Part 1, 6.1.2.2.5. Also the interaction equations shall be assessed.
The partial safety factor γ_2 shall be assessed according to Part 1, 6.1.2.2.2.

Design: Anchors tested by this option shall be designed according to design method A of Annex C.

Option 7

Goal: Determination of different characteristic loads for different load directions and different failure modes for concrete strength classes C20/25 to C50/60 in non-cracked concrete.
The spacing $s_{cr,N}$ and edge distance $c_{cr,N}$ are valid for the characteristic resistances of the anchor under tension loading as well as under shear loading with pryout failure. The characteristic shear resistance for anchors near an edge is evaluated as a function of the edge distance c_1. The spacing $s_{cr,V}$ and edge distance $c_{cr,V}$ for shear loading and concrete failure mode is determined by tests.
Also s_{min} and c_{min} for all failure modes and for a reduced characteristic load are determined.

Applicant`s choice, assessment and design:
see Option 8.

The spacings s_{cr}, s_{min} and edge distances c_{cr} and c_{min} evaluated for C20/25 are valid for all concrete strength classes C20/25 to C 50/60.

Options 6 to 1

The Options given for anchors for use in non-cracked concrete only are also available for anchors for use in cracked and non-cracked concrete. In the latter, additional tests are required with single anchors under tension, shear and combined tension and shear loadings to deduce the corresponding characteristic failure load in cracked concrete.

Tests in cracked concrete under combined tension and shear loads shall be carried out with angles of 30° and 60° in order to confirm the interaction diagram.

Spacing and edge distances evaluated for non-cracked concrete are also valid for cracked concrete.

Notes

In the tables the following notes are used:

<u>Note 1</u>

The tests may be omitted, if it can be shown that the condition given in Part 1, 6.1.2.2.5 is fulfilled.

<u>Note 2</u>

The number of tests may be reduced to 50 %, if the anchor behaviour is within current experience (see Chapter 3.2).

<u>Note 3</u>

The number of tests may be reduced to 50 %, if concrete cone failure loads agree with current experience of single anchors without spacing and edge effects and the edge distance is chosen as given in Equation (2.6).

Note 4

If concrete cone failure loads of single anchors without spacing and edge effects agree with current experience and the chosen characteristic spacing corresponds to the value given in Equation (2.5), then only tests with size "s" are required.

Note 5

Tests may be omitted, if it can be confirmed that the failure loads are equal or higher than under other loading directions.

Note 6

The value of c_1 shall be chosen so, that failure is caused by concrete failure.

Note 7

The tests may be omitted, if the tests with single anchors at the edge with shear loading towards the edge show that the failure load of the anchor can be predicted by Equation (2.10), if appropriate, taking into account additional influencing factors (eg. thickness of concrete member according to design method A in Annex C, 5.2.3.3).
The values for spacing $s_{cr,V}$ and $c_{cr,V}$ shall be taken from Equations (2.12) and (2.13).

Note 8

The tests may be omitted, if in the tests in concrete members C20/25 failure is caused by rupture of the steel.

Note 9

The tests may be omitted, if the test results with single anchors in non-cracked concrete are predictable according to Equation (2.10), if appropriate, taking into account the influence of concrete member thickness according to design method A in Annex C, 5.2.3.3. A reduction factor 0,7 can be assumed to be on the safe side for taking into account concrete cracking.

Note 10

If current experience is accepted (see 2.3.3) than only tests with one anchor size are needed. The embedment depth of this anchor size should be close to but larger than 60 mm. If different types of anchors of one size are available the stiffest anchor with the highest steel capacity shall be chosen.
The spacing shall be equal to $s = s_{cr,N}$. However if steel failure occurs than the spacing may be reduced to the largest value which ensures concrete pryout failure. In this case, the influence of the spacing on the failure load may be calculated with the factor $A_{c,N} / A^0_{c,N}$ according to the design method A in Annex C.

Note 11

The member thickness shall equal to the minimum value which will be given in the ETA.

Note 12

The member thickness may be larger than the minimum value which will be given in the ETA.

Note 13

This test series with at least 5 tests per sizes is required only if the anchor has a significantly reduced section along the length of the bolt or the sleeve of a sleeve type anchor should be considered or for internal threaded parts.

Note 14

5 tests per sizes are sufficient if a model for all anchor sizes for splitting failure is used

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Option 1 **Test programme, with the number of required tests**

Failure load of single anchors without spacing and edge effects

	direction of loading		tension				shear				combined tension and shear					
											45°		30°		60°	
	condition of concrete member		non-cracked		cracked		non-cracked		cracked		non-cracked		cracked		cracked	
	concrete compressive strength class		C 20/25	C 50/60	C 20/25	C 50/60	C 20/25	C 50/60	C 20/25	C 50/60	C 20/25	C 50/60	C 20/25	C 50/60	C 20/25	C 50/60
1	**Notes**		2,12	2, 8,12	2,12	2, 8,12	2,12	2, 8,12	2,12	2, 8,12	2,12	2, 8,12	2,12	2, 8,12	2,12	2, 8,12
	Size of anchor	s	6	10	10	10	10	10	10	10	10	10	5	5	5	5
		i	6	10	10	10	10	10	10	10	10	10	5	5	5	5
		m	6	10	10	10	10	10	10	10	10	10	5	5	5	5
		i	6	10	10	10	10	10	10	10	10	10	5	5	5	5
		l	6	10	10	10	10	10	10	10	10	10	5	5	5	5

Spacing, tests with quadruple fastenings without edge effects, $s_1 = s_2 = s_{cr,N}$

2	**Notes**		4, 12				10,12									
	Size of anchor	s	5				5									
		i	5				5									
		m	5				5									
		i	5				5									
		l	-				-									

Edge distance, tests with single anchors without spacing effects, tension test with $c_1 = c_2 = c_{cr,N}$, shear test with c_1, $c_2 \geq c_{cr,V}$

3	**Notes**		3,11				2, 6,12	2,6,8,12	2,6,9,12							
	Size of anchor	s	8				8	8	8							
		i	8				8	8	8							
		m	8				8	8	8							
		i	8				8	8	8							
		l	8				8	8	8							

Spacing and edge distance, test with double fastenings parallel to the edge, c_1, $c_2 = c_{cr,V}$, $s = 2\ c_{cr,V}$

4	**Notes**						6, 7,12									
	Size of anchor	s					8									
		i					8									
		m					8									
		i					8									
		l					8									

Minimum spacing and edge distance, tests with double fastenings parallel to the edge, $s = s_{min}$, $c_1 = c_{min}$ in C 20/25

(in general, load application by torque)

5	**Notes**		11
	Size of anchor	s	10
		i	10
		m	10
		i	10
		l	10

size of anchor: s = smallest; i = intermediate; m = medium; i = intermediate; l = largest

Option 2 **Test programme, with the number of required tests**

Failure load of single anchors without spacing and edge effects

	direction of loading		tension				shear				combined tension and shear					
											45°		30°		60°	
	condition of concrete member		non-cracked		cracked		non-cracked		cracked		non-cracked		cracked		cracked	
	concrete compressive strength class		C 20/25	C 50/60	C 20/25	C 50/60	C 20/25	C 50/60	C 20/25	C 50/60	C 20/25	C 50/60	C 20/25	C 50/60	C 20/25	C 50/60
1	**Notes**		2,12		2,12		2,12		2,12		2,12		2,12		2,12	
	Size of anchor	s	6		10		10		10		10		5		5	
		i	6		10		10		10		10		5		5	
		m	6		10		10		10		10		5		5	
		i	6		10		10		10		10		5		5	
		l	6		10		10		10		10		5		5	

Spacing, tests with quadruple fastenings without edge effects, $s_1 = s_2 = s_{cr,N}$

2	**Notes**		4,12				10,12									
	Size of anchor	s	5				5									
		i	5				5									
		m	5				5									
		i	5				5									
		l	-				-									

Edge distance, tests with single anchors without spacing effects, tension test with $c_1 = c_2 = c_{cr,N}$, shear test with $c_1, c_2 \geq c_{cr,V}$

3	**Notes**		3,11				2, 6,12		2,6,9,12							
	Size of anchor	s	8				8		8							
		i	8				8		8							
		m	8				8		8							
		i	8				8		8							
		l	8				8		8							

Spacing and edge distance, tests with double fastenings parallel to the edge, $c_1, c_2 = c_{cr,V}$, $s = 2\ c_{cr,V}$

4	**Notes**						6, 7,12									
	Size of anchor	s					8									
		i					8									
		m					8									
		i					8									
		l					8									

Minimum spacing and edge distance, tests with double fastenings parallel to the edge, $s = s_{min}$, $c_1 = c_{min}$ in C 20/25

(in general, load application by torque)

5	**Notes**		11
	Size of anchor	s	10
		i	10
		m	10
		i	10
		l	10

size of anchor: s = smallest; i = intermediate; m = medium; i = intermediate; l = largest

Option 3 **Test programme, with the required number of tests**

Failure load of single anchors without spacing and edge effects

	direction of loading		tension				shear				combined tension and shear					
											45°		30°		60°	
	condition of concrete member		non-cracked		cracked		non-cracked		cracked		non-cracked		cracked		cracked	
	concrete compressive strength class		C 20/25	C 50/60	C 20/25	C 50/60	C 20/25	C 50/60	C 20/25	C 50/60	C 20/25	C 50/60	C 20/25	C 50/60	C 20/25	C 50/60
	Notes		2,12	2, 8,12	2,12	2, 8,12			5,12	5, 8,12	5,12	5, 8,12	5,12	5, 8,12	5,12	5, 8,12
1	Size of anchor	s	6	10	10	10			10	10	10	10	5	5	5	5
		i	6	10	10	10			10	10	10	10	5	5	5	5
		m	6	10	10	10			10	10	10	10	5	5	5	5
		i	6	10	10	10			10	10	10	10	5	5	5	5
		l	6	10	10	10			10	10	10	10	5	5	5	5

Spacing, tests with quadruple fastenings without edge effects, $s_1 = s_2 = s_{cr}$

	Notes		4,12													
2	Size of anchor	s	5													
		i	5													
		m	5													
		i	5													
		l	-													

Edge distance, tests with single anchors without spacing effects, tension test with $c_1 = c_2 = c_{cr}$

	Notes		3,11													
3	Size of anchor	s	8													
		i	8													
		m	8													
		i	8													
		l	8													

Spacing and edge distance, test with double fastenings parallel to the edge, $c_1 = c_2 = c_{cr}$, $s = s_{cr}$

	Notes						2,11	2,5,8,11								
4	Size of anchor	s					8	8								
		i					8	8								
		m					8	8								
		i					8	8								
		l					8	8								

Minimum spacing and edge distance, tests with double fastenings parallel to the edge, $s = s_{min}$, $c_1 = c_{min}$ in C 20/25

(in general, load application by torque)

	Notes		11
5	Size of anchor	s	10
		i	10
		m	10
		i	10
		l	10

size of anchor: s = smallest; i = intermediate; m = medium; i = intermediate; l = largest

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Option 4 **Test programme, with the required number of tests**

Failure load of single anchors without spacing and edge effects

	direction of loading		tension				shear				combined tension and shear					
											45°		30°		60°	
	condition of concrete member		non-cracked		cracked		non-cracked		cracked		non-cracked		cracked		cracked	
	concrete compressive strength class		C 20/25	C 50/60	C 20/25	C 50/60	C 20/25	C 50/60	C 20/25	C 50/60	C 20/25	C 50/60	C 20/25	C 50/60	C 20/25	C 50/60
1	**Notes**		2,12		2,12				5,12		5,12		5,12		5,12	
	Size of anchor	s	6		10				10		10		5		5	
		i	6		10				10		10		5		5	
		m	6		10				10		10		5		5	
		i	6		10				10		10		5		5	
		l	6		10				10		10		5		5	

Spacing, tests with quadruple fastenings without edge effects, $s_1 = s_2 = s_{cr}$

2	**Notes**		4,12													
	Size of anchor	s	5													
		i	5													
		m	5													
		i	5													
		l	-													

Edge distance, tests with single anchors without spacing effects, tension test with $c_1 = c_2 = c_{cr}$

3	**Notes**		3,11													
	Size of anchor	s	8													
		i	8													
		m	8													
		i	8													
		l	8													

Spacing and edge distance, tests with double fastenings parallel to the edge, $c_1 = c_2 = c_{cr}$, $s = s_{cr}$

4	**Notes**						2,11									
	Size of anchor	s					8									
		i					8									
		m					8									
		i					8									
		l					8									

Minimum spacing and edge distance, tests with double fastenings parallel to the edge, $s = s_{min}$, $c_1 = c_{min}$ in C 20/25

(in general, load application by torque)

5	**Notes**		11
	Size of anchor	s	10
		i	10
		m	10
		i	10
		l	10

size of anchor: s = smallest; i = intermediate; m = medium; i = intermediate; l = largest

91693.97

Option 5 **Test programme, with the number of required tests**

Failure load of single anchors without spacing and edge effects

		direction of loading	tension				shear				combined tension and shear					
											45°		30°		60°	
		condition of concrete member	non-cracked		cracked		non-cracked		cracked		non-cracked		cracked		cracked	
		concrete compressive strength class	C 20/25	C 50/60	C 20/25	C 50/60	C 20/25	C 50/60	C 20/25	C 50/60	C 20/25	C 50/60	C 20/25	C 50/60	C 20/25	C 50/60
1	**Notes**		2,12	2, 8,12	2,12	2, 8,12			5,12	5, 8,12	5,12	5, 8,12	5,12	5, 8,12	5,12	5, 8,12
	Size of anchor	s	6	10	10	10			10	10	10	10	5	5	5	5
		i	6	10	10	10			10	10	10	10	5	5	5	5
		m	6	10	10	10			10	10	10	10	5	5	5	5
		i	6	10	10	10			10	10	10	10	5	5	5	5
		l	6	10	10	10			10	10	10	10	5	5	5	5

Spacing, tests with quadruple fastenings without edge effects, $s_1 = s_2 = s_{cr}$

2	**Notes**		4,12													
	Size of anchor	s	5													
		i	5													
		m	5													
		i	5													
		l	-													

Edge distance, tests with single anchors without spacing effects, tension test with $c_1 = c_2 = c_{cr}$

3	**Notes**		3,11													
	Size of anchor	s	8													
		i	8													
		m	8													
		i	8													
		l	8													

Spacing and edge distance, test with double fastenings parallel to the edge, $c_1 = c_2 = c_{cr}$, $s = s_{cr}$

4	**Notes**						2,11	2,5,8,11								
	Size of anchor	s					8	8								
		i					8	8								
		m					8	8								
		i					8	8								
		l					8	8								

Minimum spacing and edge distance, tests with double fastenings parallel to the edge, $s = s_{cr}$, $c_1 = c_{cr}$ in C 20/25

(in general, load application by torque)

5	**Notes**		1,11
	Size of anchor	s	10
		i	10
		m	10
		i	10
		l	10

size of anchor: s = smallest; i = intermediate; m = medium; i = intermediate; l = largest

Option 6 **Test programme, with the number of required tests**

Failure load of single anchors without spacing and edge effects

	direction of loading		tension				shear				combined tension and shear					
											45°		30°		60°	
	condition of concrete member		non-cracked		cracked		non-cracked		cracked		non-cracked		cracked		cracked	
	concrete compressive strength class		C 20/25	C 50/60	C 20/25	C 50/60	C 20/25	C 50/60	C 20/25	C 50/60	C 20/25	C 50/60	C 20/25	C 50/60	C 20/25	C 50/60
1	**Notes**		2,12		2,12				5,12		5,12		5,12		5,12	
	Size of anchor	s	6		10				10		10		5		5	
		i	6		10				10		10		5		5	
		m	6		10				10		10		5		5	
		i	6		10				10		10		5		5	
		l	6		10				10		10		5		5	

Spacing, tests with quadruple fastenings without edge effects, $s_1 = s_2 = s_{cr}$

2	**Notes**		4,12													
	Size of anchor	s	5													
		i	5													
		m	5													
		i	5													
		l	-													

Edge distance, tests with single anchors without spacing effects, tension test with $c_1 = c_2 = c_{cr}$

3	**Notes**		3,11													
	Size of anchor	s	8													
		i	8													
		m	8													
		i	8													
		l	8													

Spacing and edge distance, tests with double fastenings parallel to the edge, $c_1 = c_2 = c_{cr}$, $s = s_{cr}$

4	**Notes**						2,11									
	Size of anchor	s					8									
		i					8									
		m					8									
		i					8									
		l					8									

Minimum spacing and edge distance, tests with double fastenings parallel to the edge, $s = s_{cr}$, $c_1 = c_{cr}$ in C 20/25

5	**Notes**		1,11
	Size of anchor	s	10
		i	10
		m	10
		i	10
		l	10

(in general, load application by torque)

size of anchor: s = smallest; i = intermediate; m = medium; i = intermediate; l = largest

Option 7 **Test programme, with the number of required tests**

Failure load of single anchors without spacing and edge effects

	direction of loading	tension				shear				combined tension and shear					
										45°		30°		60°	
	condition of concrete member	non-cracked		cracked		non-cracked		cracked		non-cracked		cracked		cracked	
	concrete compressive strength class	C 20/25	C 50/60	C 20/25	C 50/60	C 20/25	C 50/60	C 20/25	C 50/60	C 20/25	C 50/60	C 20/25	C 50/60	C 20/25	C 50/60
	Notes	2,12	2, 8,12			2,12	2, 8,12			2,12	2, 8,12				
	s	6	10			10	10			10	10				
1	Size of i	6	10			10	10			10	10				
	anchor m	6	10			10	10			10	10				
	i	6	10			10	10			10	10				
	l	6	10			10	10			10	10				

Spacing, tests with quadruple fastenings without edge effects, $s_1 = s_2 = s_{cr,N}$

	Notes	4,12				10,12									
	s	5				5									
2	Size of i	5				5									
	anchor m	5				5									
	i	5				5									
	l	-				-									

Edge distance, tests with single anchors without spacing effects, tension test with $c_1 = c_2 = c_{cr,N}$, shear test with $c_1, c_2 \geq c_{cr,V}$

	Notes	3,11				2, 6,12	2,6,8,12								
	s	8				8	8								
3	Size of i	8				8	8								
	anchor m	8				8	8								
	i	8				8	8								
	l	8				8	8								

Spacing and edge distance, test with double fastenings parallel to the edge, $c_1, c_2 = c_{cr,V}$, $s = 2\ c_{cr,V}$

	Notes					6, 7,12									
	s					8									
4	Size of i					8									
	anchor m					8									
	i					8									
	l					8									

Minimum spacing and edge distance, tests with double fastenings parallel to the edge, $s = s_{min}$, $c_1 = c_{min}$ in C 20/25

(in general, load application by torque)

	Notes	11
	s	10
5	Size of i	10
	anchor m	10
	i	10
	l	10

size of anchor: s = smallest; i = intermediate; m = medium; i = intermediate; l = largest

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Option 8 **Test programme, with the number of required tests**

Failure load of single anchors without spacing and edge effects

	direction of loading		tension				shear				combined tension and shear					
											45°		30°		60°	
	condition of concrete member		non-cracked		cracked		non-cracked		cracked		non-cracked		cracked		cracked	
	concrete compressive strength class		C 20/25	C 50/60	C 20/25	C 50/60	C 20/25	C 50/60	C 20/25	C 50/60	C 20/25	C 50/60	C 20/25	C 50/60	C 20/25	C 50/60
1	**Notes**		2,12				2,12				2,12					
	Size of anchor	s	6				10				10					
		i	6				10				10					
		m	6				10				10					
		i	6				10				10					
		l	6				10				10					

Spacing, tests with quadruple fastenings without edge effects, $s_1 = s_2 = s_{cr,N}$

2	**Notes**		4,12				10,12									
	Size of anchor	s	5				5									
		i	5				5									
		m	5				5									
		i	5				5									
		l	-				-									

Edge distance, tests with single anchors without spacing effects, tension test with $c_1 = c_2 = c_{cr,N}$, shear test with $c_1, c_2 \geq c_{cr,V}$

3	**Notes**		3,11				2, 6,12									
	Size of anchor	s	8				8									
		i	8				8									
		m	8				8									
		i	8				8									
		l	8				8									

Spacing and edge distance, tests with double fastenings parallel to the edge, $c_1, c_2 = c_{cr,V}$, $s = 2\ c_{cr;V}$

4	**Notes**						6, 7,12									
	Size of anchor	s					8									
		i					8									
		m					8									
		i					8									
		l					8									

Minimum spacing and edge distance, tests with double fastenings parallel to the edge, $s = s_{min}$, $c_1 = c_{min}$ in C 20/25

(in general, load application by torque)

5	**Notes**		11
	Size of anchor	s	10
		i	10
		m	10
		i	10
		l	10

size of anchor: s = smallest; i = intermediate; m = medium; i = intermediate; l = largest

Option 9 **Test programme, with the number of required tests**

Failure load of single anchors without spacing and edge effects

	direction of loading	tension				shear				combined tension and shear					
										45°		30°		60°	
	condition of concrete member	non-cracked		cracked		non-cracked		cracked		non-cracked		cracked		cracked	
	concrete compressive strength class	C 20/25	C 50/60	C 20/25	C 50/60	C 20/25	C 50/60	C 20/25	C 50/60	C 20/25	C 50/60	C 20/25	C 50/60	C 20/25	C 50/60
	Notes	2,12	2, 8,12							5,12	5, 8,12				
1	Size of anchor s	6	10							10	10				
	i	6	10							10	10				
	m	6	10							10	10				
	i	6	10							10	10				
	l	6	10							10	10				

Spacing, tests with quadruple fastenings without edge effects, $s_1 = s_2 = s_{cr}$

	Notes	4,12													
2	Size of anchor s	5													
	i	5													
	m	5													
	i	5													
	l	-													

Edge distance, tests with single anchors without spacing effects, tension test with $c_1 = c_2 = c_{cr}$

	Notes	3,11													
3	Size of anchor s	8													
	i	8													
	m	8													
	i	8													
	l	8													

Spacing and edge distance, test with double fastenings parallel to the edge, $c_1 = c_2 = c_{cr}$, $s = s_{cr}$

	Notes					2,11	2,5,8,11								
4	Size of anchor s					8	8								
	i					8	8								
	m					8	8								
	i					8	8								
	l					8	8								

Minimum spacing and edge distance, tests with double fastenings parallel to the edge, $s = s_{min}$, $c_1 = c_{min}$ in C 20/25

(in general, load application by torque)

	Notes	11
5	Size of anchor s	10
	i	10
	m	10
	i	10
	l	10

size of anchor: s = smallest; i = intermediate; m = medium; i = intermediate; l = largest

Option 10 **Test programme, with the number of required tests**

Failure load of single anchors without spacing and edge effects

	direction of loading	tension				shear				combined tension and shear 45°		30°		60°	
	condition of concrete member	non-cracked		cracked		non-cracked		cracked		non-cracked		cracked		cracked	
	concrete compressive strength class	C 20/25	C 50/60	C 20/25	C 50/60	C 20/25	C 50/60	C 20/25	C 50/60	C 20/25	C 50/60	C 20/25	C 50/60	C 20/25	C 50/60
1	**Notes**	2,12								5,12					
	Size of anchor s	6								10					
	i	6								10					
	m	6								10					
	i	6								10					
	l	6								10					

Spacing, tests with quadruple fastenings without edge effects, $s_1 = s_2 = s_{cr}$

2	**Notes**	4,12											
	Size of anchor s	5											
	i	5											
	m	5											
	i	5											
	l	-											

Edge distance, tests with single anchors without spacing effects, tension test with $c_1 = c_2 = c_{cr}$

3	**Notes**	3,11											
	Size of anchor s	8											
	i	8											
	m	8											
	i	8											
	l	8											

Spacing and edge distance, tests with double fastenings parallel to the edge, $c_1 = c_2 = c_{cr}$, $s = s_{cr}$

4	**Notes**					2,11							
	Size of anchor s					8							
	i					8							
	m					8							
	i					8							
	l					8							

Minimum spacing and edge distance, tests with double fastenings parallel to the edge, $s = s_{min}$, $c_1 = c_{min}$ in C 20/25

5	**Notes**	11
	Size of anchor s	10
	i	10
	m	10
	i	10
	l	10

(in general, load application by torque)

size of anchor: s = smallest; i = intermediate; m = medium; i = intermediate; l = largest

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Option 11 **Test programme, with the number of required tests**

Failure load of single anchors without spacing and edge effects

	direction of loading		tension				shear				combined tension and shear					
											45°		30°		60°	
	condition of concrete member		non-cracked		cracked		non-cracked		cracked		non-cracked		cracked		cracked	
	concrete compressive strength class		C 20/25	C 50/60	C 20/25	C 50/60	C 20/25	C 50/60	C 20/25	C 50/60	C 20/25	C 50/60	C 20/25	C 50/60	C 20/25	C 50/60
	Notes		2,12	2, 8,12							5,12	5, 8,12				
1	Size of anchor	s	6	10							10	10				
		i	6	10							10	10				
		m	6	10							10	10				
		i	6	10							10	10				
		l	6	10							10	10				

Spacing, tests with quadruple fastenings without edge effects, $s_1 = s_2 = s_{cr}$

	Notes		4,12													
2	Size of anchor	s	5													
		i	5													
		m	5													
		i	5													
		l	-													

Edge distance, tests with single anchors without spacing effects, tension test with $c_1 = c_2 = c_{cr}$

	Notes		3,11													
3	Size of anchor	s	8													
		i	8													
		m	8													
		i	8													
		l	8													

Spacing and edge distance, test with double fastenings parallel to the edge, $c_1 = c_2 = c_{cr}$, $s = s_{cr}$

	Notes						2,11	2,5,8,11								
4	Size of anchor	s					8	8								
		i					8	8								
		m					8	8								
		i					8	8								
		l					8	8								

Minimum spacing and edge distance, tests with double fastenings parallel to the edge, $s = s_{cr}$, $c_1 = c_{cr}$ in C 20/25

(in general, load application by torque)

	Notes		1,11
5	Size of anchor	s	10
		i	10
		m	10
		i	10
		l	10

size of anchor: s = smallest; i = intermediate; m = medium; i = intermediate; l = largest

91693.97

Option 12 **Test programme, with the number of required tests**

Failure load of single anchors without spacing and edge effects

	direction of loading		tension				shear				combined tension and shear					
											45°		30°		60°	
	condition of concrete member		non-cracked		cracked		non-cracked		cracked		non-cracked		cracked		cracked	
	concrete compressive strength class		C 20/25	C 50/60	C 20/25	C 50/60	C 20/25	C 50/60	C 20/25	C 50/60	C 20/25	C 50/60	C 20/25	C 50/60	C 20/25	C 50/60
1	**Notes**		2,12								5,12					
	Size of anchor	s	6								10					
		i	6								10					
		m	6								10					
		i	6								10					
		l	6								10					

Spacing, tests with quadruple fastenings without edge effects, $s_1 = s_2 = s_{cr}$

2	**Notes**		4,12													
	Size of anchor	s	5													
		i	5													
		m	5													
		i	5													
		l	-													

Edge distance, tests with single anchors without spacing effects, tension test with $c_1 = c_2 = c_{cr}$

3	**Notes**		3,11													
	Size of anchor	s	8													
		i	8													
		m	8													
		i	8													
		l	8													

Spacing and edge distance, test with double fastenings parallel to the edge, $c_1 = c_2 = c_{cr}$, $s = s_{cr}$

4	**Notes**						2,11									
	Size of anchor	s					8									
		i					8									
		m					8									
		i					8									
		l					8									

Minimum spacing and edge distance, tests with double fastenings parallel to the edge, $s = s_{cr}$, $c_1 = c_{cr}$ in C 20/25

(in general, load application by torque)

5	**Notes**		1,11
	Size of anchor	s	10
		i	10
		m	10
		i	10
		l	10

size of anchor: s = smallest; i = intermediate; m = medium; i = intermediate; l = largest

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Option 1, 3 and 5 **Reduced test programme, if the design model of Annex C is used**

Failure load of single anchors without spacing and edge effects

		direction of loading	tension				shear			
		condition of concrete member	non-cracked		cracked		non-cracked		cracked	
		concrete compressive strength class	C 20/25	C 50/60	C 20/25	C 50/60	C 20/25	C 50/60	C 20/25	C 50/60
1		**Notes**	12	8,12	12	12	12, 13			
	Size of anchor	s	5	5	5	5	5			
		i	5	5	5	5	5			
		m	5	5	5	5	5			
		i	5	5	5	5	5			
		l	5	5	5	5	5			

Edge distance, tests with single anchors without spacing effects, tension test with $c_1 = c_2 = c_{cr,N}$, shear test with $c_1, c_2 \geq c_{cr,V}$

3		**Notes**	11			
	Size of anchor	s	4			
		i	4			
		m	4			
		i	4			
		l	4			

Minimum spacing and edge distance, tests with double fastenings parallel to the edge, $s = s_{min}$, $c_1 = c_{min}$ in C 20/25

(in general, load application by torque)

5		**Notes**	11, 14
	Size of anchor	s	5
		i	5
		m	5
		i	5
		l	5

size of anchor: s = smallest; i = intermediate; m = medium; i = intermediate; l = largest

Option 2, 4 and 6 **Reduced test programme, if the design model of Annex C is used**

Failure load of single anchors without spacing and edge effects

	direction of loading		tension				shear			
	condition of concrete member		non-cracked		cracked		non-cracked		cracked	
	concrete compressive strength class		C 20/25	C 50/60	C 20/25	C 50/60	C 20/25	C 50/60	C 20/25	C 50/60
1	**Notes**		12		12		12, 13			
	Size of anchor	s	5		5		5			
		i	5		5		5			
		m	5		5		5			
		i	5		5		5			
		l	5		5		5			

Edge distance, tests with single anchors without spacing effects, tension test with $c_1 = c_2 = c_{cr,N}$, shear test with c_1, $c_2 \geq c_{cr,V}$

3	**Notes**		11			
	Size of anchor	s	4			
		i	4			
		m	4			
		i	4			
		l	4			

Minimum spacing and edge distance, tests with double fastenings parallel to the edge, $s = s_{min}$, $c_1 = c_{min}$ in C 20/25

(in general, load application by torque)

5	**Notes**		11, 14
	Size of anchor	s	5
		i	5
		m	5
		i	5
		l	5

size of anchor: s = smallest; i = intermediate; m = medium; i = intermediate; l = largest

Option 7, 9 and 11 **Reduced test programme, if the design model of Annex C is used**

Failure load of single anchors without spacing and edge effects

	direction of loading		tension				shear			
	condition of concrete member		non-cracked		cracked		non-cracked		cracked	
	concrete compressive strength class		C 20/25	C 50/60	C 20/25	C 50/60	C 20/25	C 50/60	C 20/25	C 50/60
1	**Notes**		12	8,12			12, 13			
	Size of anchor	s	5	5			5			
		i	5	5			5			
		m	5	5			5			
		i	5	5			5			
		l	5	5			5			

Edge distance, tests with single anchors without spacing effects, tension test with $c_1 = c_2 = c_{cr,N}$, shear test with c_1, $c_2 \geq c_{cr,V}$

3	**Notes**		11			
	Size of anchor	s	4			
		i	4			
		m	4			
		i	4			
		l	4			

Minimum spacing and edge distance, tests with double fastenings parallel to the edge, $s = s_{min}$, $c_1 = c_{min}$ in C 20/25

(in general, load application by torque)

5	**Notes**		11, 14
	Size of anchor	s	5
		i	5
		m	5
		i	5
		l	5

size of anchor: s = smallest; i = intermediate; m = medium; i = intermediate; l = largest

Option 8, 10 and 12 **Reduced test programme, if the design model of Annex C is used**

Failure load of single anchors without spacing and edge effects

		direction of loading	tension				shear			
		condition of concrete member	non-cracked		cracked		non-cracked		cracked	
		concrete compressive strength class	C 20/25	C 50/60	C 20/25	C 50/60	C 20/25	C 50/60	C 20/25	C 50/60
1	**Notes**		12				12, 13			
	Size of anchor	s	5				5			
		i	5				5			
		m	5				5			
		i	5				5			
		l	5				5			

Edge distance, tests with single anchors without spacing effects, tension test with $c_1 = c_2 = c_{cr,N}$, shear test with c_1, $c_2 \geq c_{cr,V}$

3	**Notes**		11			
	Size of anchor	s	4			
		i	4			
		m	4			
		i	4			
		l	4			

Minimum spacing and edge distance, tests with double fastenings parallel to the edge, $s = s_{min}$, $c_1 = c_{min}$ in C 20/25

(in general, load application by torque)

5	**Notes**		11, 14
	Size of anchor	s	5
		i	5
		m	5
		i	5
		l	5

size of anchor: s = smallest; i = intermediate; m = medium; i = intermediate; l = largest