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EAD **330008-04-0601-v01**

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European Assessment Document for

Variant: Anchor channels under fatigue cyclic shear with different lower load level

This European Assessment Document (EAD) has been developed taking into account up-to-date technical and scientific knowledge at the time of issue and is published in accordance with the relevant provisions of Regulation No (EU) 305/2011 as a basis for the preparation and issuing of European Technical Assessments (ETA).

Contents

1 SCOPE OF THE EAD

1.1 Description of the construction product

EAD 330008-04-0601 [1], clause 1.1, applies with the following amendments.

This EAD is a variant to EAD 330008-04-0601 due to the fact that EAD 330008-04-0601 does not cover fatigue shear. EAD 330008-04-0601-v01 covers anchor channels under fatigue cyclic shear with different lower load level, in the following referred to as “anchor channels".

1.2 Information on the intended use of the construction product

1.2.1 Intended use

EAD 330008-04-0601 [1], clause 1.2.1, applies with the following amendments. The products covered by this EAD variant are intended to be used for design situations as covered by EOTA TR050:2023 [2].

In addition, anchor channels used to transmit fatigue pulsating shear loads perpendicular (y) to the longitudinal (x) channel axis, fatigue pulsating shear loads in the direction (x) of the longitudinal channel axis or any combination thereof into the concrete where the annular gap between the hole in the fixture and the channel bolt as well as the gap between the channel bolt and the channel lips are eliminated, e.g., by filling with injection mortar, are covered.

The relevant loading procedure (different load ranges in the pulsating range with constant lower load close to zero or with different level of lower load (not zero) or with constant upper load) depends on the intended use in design of the fastenings, given by the manufacturer in its technical file.

The product is intended to be subjected to shear loads without lever arm in accordance with EN 1992-4[1], clause 6.2.2.3 (1) a) and b) 1). Neither a levelling mortar according to EN 1992-4, clause 6.2.2.3 (1) b) 2) nor a stand-off installation according to EN 1992-4, Figure 6.6, are covered. The product is intended to be used for anchorages far from edges. This is assumed if the edge distance $c \geq \max\{10\ h_{ef};\ 60\ d_a\}$ for all directions.

1.2.2 Working life/Durability

EAD 330008-04-0601 [1] applies.

1 All undated references to standards in this EAD are to be understood as references to the dated versions listed in chapter 4.

1.3 Specific terms used in this EAD

EAD 330008-04-0601 [1], clause 1.3, applies with the following amendments.

Additional to EAD 330008-04-0601 [1] following symbols are used:

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

$\Delta V_{Rk,s,y,lo,n}$	=	Characteristic fatigue resistance to steel failure under cyclic shear loading perpendicular (y) to the longitudinal (x) channel axis	[N]
$V_{lok,s,y,n}$	=	Characteristic value of lower load level relevant for steel resistance under cyclic shear loading perpendicular (y) to the longitudinal (x) channel axis	[N]
$\Delta V_{Rk,s,x,lo,n}$	=	Characteristic fatigue resistance to steel failure under cyclic shear loading in the direction of the longitudinal (x) channel axis	[N]
$V_{lok,s,x,n}$	=	Characteristic value of lower load level relevant for steel resistance under cyclic shear loading in the direction of the longitudinal (x) channel axis	[N]
$\Delta V_{Rk,cp,y,E,n}$	=	Characteristic fatigue resistance to concrete pry-out failure under cyclic shear loading perpendicular (y) to the longitudinal (x) channel axis	[N]
$\Delta V_{Rk,cp,x,E,n}$	=	Characteristic fatigue resistance to concrete pry-out failure under cyclic shear loading in the direction of the longitudinal (x) channel axis	[N]
$V_{y,Elok}$	=	Characteristic lower cyclic shear load perpendicular (y) to the longitudinal (x) channel axis	[N]
$V_{x,Elok}$	=	Characteristic lower cyclic shear load in the direction of the longitudinal (x) channel axis	[N]
k_{sn}	=	Exponent for combined tension and shear verification regarding steel failure	[-]
$\eta_{k,cp,Vy,fat}$	=	Reduction factor for fatigue resistance to concrete pry-out failure perpendicular (y) to the longitudinal (x) channel axis	[-]
$\eta_{k,cp,Vx,fat}$	=	Reduction factor for fatigue resistance to concrete pry-out failure in the direction of the longitudinal (x) channel axis	[-]
$V_{Rk,cp}$	=	Characteristic value of static resistance to concrete pry-out failure according to EN 1992-4, Equation (7.76a)	[N]
$S_{y,lok}$	=	utilisation of static resistance to shear load perpendicular (y) to the longitudinal (x) channel axis	[-]
$S_{x,lok}$	=	utilisation of static resistance to shear load in the direction of the longitudinal (x) channel axis	[-]
$V_{k,y,ref}$	=	Characteristic value of the reference static shear resistance perpendicular (y) to the longitudinal (x) channel axis	[N]
$V_{k,x,ref}$	=	Characteristic value of the reference static shear resistance in the direction of the longitudinal (x) channel axis	[N]
ΔV_y	=	load range of fatigue cyclic shear loading perpendicular (y) to longitudinal (x) channel axis	[N]
ΔV_x	=	load range of fatigue cyclic shear loading in the direction of longitudinal (x) channel axis	[N]
$\lg n$	=	$\log_{10} n$	[-]
n	=	Number of load cycles	[-]
$\ln\ 10$	=	$\log_e 10$	[-]
e	=	Euler's number	[-]

2 ESSENTIAL CHARACTERISTICS AND RELEVANT ASSESSMENT METHODS AND CRITERIA

2.1 Essential characteristics of the product

Table 2.1.1 shows how the performance of the anchor channels is assessed in relation to the essential characteristics.

Table 2.1.1 Essential characteristics of the product and methods and criteria for assessing the performance of the product in relation to those essential characteristics

No	Essential characteristic	Assessment method	Expression of product performance
Basic Works Requirement 1: Mechanical resistance and stability			
Characteristic resistance under static and quasi-static tension loading			
1	Characteristic resistance to steel failure of anchors under static and quasi-static tension loading	EAD 330008-04-0601 [1]; Clause 2.2.1	Level $N_{Rk,s,a}$ [N]
2	Characteristic resistance to steel failure of the connection between anchors and channel under static and quasi-static tension loading	EAD 330008-04-0601 [1] Clause 2.2.2	Level $N_{Rk,s,c}$ [N]
3	Characteristic resistance to steel failure of channel lips and subsequently pull-out of channel bolt under static and quasi-static tension loading	EAD 330008-04-0601 [1] Clause 2.2.3	Level $N^0_{Rk,s,l}$ [N]; $s_{l,N}$ [mm]
4	Characteristic resistance to steel failure of channel bolt under static and quasi-static tension loading	EAD 330008-04-0601 [1] Clause 2.2.4	Level $N_{Rk,s}$ [N]
5	Characteristic resistance to steel failure by exceeding the bending strength of the channel under static and quasi-static tension loading	EAD 330008-04-0601 [1] Clause 2.2.5	Level $M_{Rk,s,flex}$ [Nm]; s_{max}[mm]
6	Maximum installation torque to avoid damage during installation	EAD 330008-04-0601 [1] Clause 2.2.6	Level $T_{inst,g}$ [Nm]; ($T_{inst,s}$) [Nm]
7	Characteristic resistance to pull-out failure of the anchor under static and quasi-static tension loading	EAD 330008-04-0601 [1] Clause 2.2.7	Level $N_{Rk,p}$ [N]
8	Characteristic resistance to concrete cone failure under static and quasi-static tension loading	EAD 330008-04-0601 [1] Clause 2.2.8	Level $k_{cr,N}$ [-]; $k_{ucr,N}$ [-]; h_{ef} [mm]
9	Minimum edge distances, spacing and member thickness to avoid concrete splitting during installation	EAD 330008-04-0601 [1] Clause 2.2.9	Level s_{min}; c_{min}; h_{min} [mm]
10	Characteristic edge distance and spacing to avoid splitting of concrete under load	EAD 330008-04-0601 [1] Clause 2.2.10	Level $s_{cr,sp}$; $c_{cr,sp}$ [mm]

No	Essential characteristic	Assessment method	Expression of product performance
11	Characteristic resistance to blowout failure - bearing area of anchor head	EAD 330008-04-0601 [1] Clause 2.2.11	Level A_h[mm²]
Characteristic resistance under static and quasi-static shear loading			
12	Characteristic resistance to steel failure of channel bolt under static and quasi-static shear loading in transverse direction without lever arm	EAD 330008-04-0601[1] Clause 2.2.12	Level $V_{Rk,s}$ [N]
13	Characteristic resistance to steel failure by bending of the channel bolt under static and quasi-static shear loading in transverse direction with lever arm	EAD 330008-04-0601 [1] Clause 2.2.13	Level $M^0_{Rk,s}$ [Nm]
14	Characteristic resistance to steel failure of channel lips, steel failure of connection between anchor and channel or steel failure of anchor under static and quasi-static shear loading in transverse direction	EAD 330008-04-0601 [1] Clause 2.2.14	Level $V^0_{Rk,s,l,y}$ [N]; $s_{l,V}$ [mm]; $V_{Rk,s,c,y}$ [N]; $V_{Rk,s,a,y}$ [N]
15	Characteristic resistance to steel failure of connection between channel lips and channel bolt under static and quasi-static shear loading in transverse direction	EAD 330008-04-0601 [1] Clause 2.2.15	Level $V_{Rk,s,l,x}$ [N]
16	Factor for sensitivity to installation (longitudinal shear)	EAD 330008-04-0601 [1] Clause 2.2.16	Level γ_{inst} [-]
17	Characteristic resistance to steel failure of the anchor anchor under static and quasi-static loading in longitudinal (x) channel axis	EAD 330008-04-0601 [1] Clause 2.2.17	Level $V_{Rk,s,a,x}$ [N]
18	Characteristic resistance to steel failure of connection between anchor and channel under static and quasi-static loading in longitudinal (x) channel axis	EAD 330008-04-0601 [1] Clause 2.2.18	Level $V_{Rk,s,c,x}$ [N]
19	Characteristic resistance to concrete pry-out failure under static and quasi-static shear loading	EAD 330008-04-0601 [1] Clause 2.2.19	Level k_8 [-]
20	Characteristic resistance to concrete edge failure under static and quasi-static shear loading (anchor channel parallel to the edge)	EAD 330008-04-0601 [1] Clause 2.2.20	Level $k_{cr,V}$ [-]; $k_{ucr,V}$ [N]
Characteristic resistance under combined static and quasi-static tension and shear loading			
21	Resistance to steel failure of the anchor channel due to combined static and quasi-static tension and shear loads on anchor channels embedded in concrete	EAD 330008-04-0601 [1] Clause 2.2.21	Level k_{13} [-]; k_{14} [-]

No	Essential characteristic	Assessment method	Expression of product performance
Characteristic resistance under fatigue tension loading			
22	Characteristic fatigue resistance to steel failure of the whole system (continuous or tri-linear function, assessment method A1, A2)	EAD 330008-04-0601 [1] Clause 2.2.22	Level $\Delta N_{Rk,s,0,n}$ [N] (n = 1 to n = ∞)
23	Characteristic fatigue limit resistance to steel failure of the whole system (assessment method B)	EAD 330008-04-0601 [1] Clause 2.2.23	Level $\Delta N_{Rk,s,0,\infty}$ [N]
24	Characteristic fatigue resistance to steel failure of the whole system (linearized function, assessment method C)	EAD 330008-04-0601 [1] Clause 2.2.24	Level $\Delta N_{Rk,s,lo,n}$ [N]; $N_{lok,s,n}$ [N] (n = 10^4 to n = ∞)
25	Characteristic fatigue resistance to concrete related failure of the whole system (exponential function, assessment method A1, A2)	EAD 330008-04-0601 [1] Clause 2.2.25	Level $\Delta N_{Rk,c,0,n}$ [N]; $\Delta N_{Rk,p,0,n}$ [N] (n = 1 to n = ∞)
26	Characteristic fatigue limit resistance to concrete related failure of the whole system (assessment method B)	EAD 330008-04-0601 [1] Clause 2.2.26	Level $\Delta N_{Rk,c,0,\infty}$ [N]; $\Delta N_{Rk,p,0,\infty}$ [N]
27	Characteristic fatigue resistance to concrete related failure of the whole system (linearized function, assessment method C)	EAD 330008-04-0601 [1] Clause 2.2.27	Level $\Delta N_{Rk,c,E,n}$ [N]; $\Delta N_{Rk,p,E,n}$ [N] (n = 10^4 to n = ∞)
Characteristic resistance under fatigue shear loading			
28	Fatigue resistance to steel failure of the whole system under shear load perpendicular (y) to the longitudinal (x) channel axis (bilinear function, assessment method C)	2.2.1	Level $\Delta V_{Rk,s,y,lo,n}$ [N]; $V_{lok,s,y,n}$ [N] (n = 10^4 to n = ∞)
29	Fatigue resistance to steel failure of the whole system under shear load in the direction (x) of the longitudinal (x) channel axis (bilinear function, assessment method C)	2.2.2	Level $\Delta V_{Rk,s,x,lo,n}$ [N];$V_{lok,s,x,n}$ [N] (n = 10^4 to n = ∞)
30	Fatigue resistance to concrete pry-out failure under shear load perpendicular (y) to the longitudinal (x) channel axis and in the direction (x) of the longitudinal channel axis (bilinear function, assessment method C)	2.2.3	Level $\Delta V_{Rk,cp,y,E,n}$ [N]; $\Delta V_{Rk,cp,x,E,n}$ [N] (n = 10^4 to n = ∞)

No	Essential characteristic	Assessment method	Expression of product performance
Characteristic resistance under combined fatigue tension and shear loading			
31	Fatigue resistance to steel failure of the whole system under combined fatigue tension and shear load (bilinear function, assessment method C)	2.2.4	Level k_{sn} [-]
Characteristic resistance under seismic loading (seismic performance category C1)			
32	Resistance to steel failure under seismic tension loading (seismic performance category C1)	EAD 330008-04-0601 [1] 2.2.28	Level $N_{Rk,s,a,eq}$ [N]; $N_{Rk,s,c,eq}$ [N]; $N^0_{Rk,s,l,eq}$ [N]; $N_{Rk,s,eq}$ [N]; $M_{Rk,s,flex,eq}$ [Nm]
33	Resistance to steel failure under seismic shear loading for shear load in transverse direction (seismic performance category C1)	EAD 330008-04-0601 [1] 2.2.29	Level $V_{Rk,s,eq}$ [N]; $V^0_{Rk,s,l,y,eq}$ [N]; $V_{Rk,s,c,y,eq}$ [N]; $V_{Rk,s,a,y,eq}$ [N]
34	Resistance to steel failure under seismic shear loading for shear load in longitudinal (x) channel axis (seismic performance category C1)	EAD 330008-04-0601 [1] 2.2.30	Level $V_{Rk,s,l,x,eq}$ [N]; $V_{Rk,s,a,x,eq}$ [N]; $V_{Rk,s,c,x,eq}$ [N]
Characteristic resistance under static and quasi-static tension and/ or shear loading			
35	Displacements	EAD 330008-04-0601 [1] 2.2.31	Level δ_{N0}; $\delta_{N\infty}$; $\delta_{V,y,0}$; $\delta_{V,y,\infty}$; $\delta_{V,x,0}$; $\delta_{V,x,\infty}$ [mm]
Basic Works Requirement 2: Safety in case of fire			
36	Reaction to fire	EAD 330008-04-0601 [1] 2.2.32	Class
37	Resistance to fire	EAD 330008-04-0601 [1] 2.2.33	Level $N_{Rk,s,fi}$ [N]; $V_{Rk,y,s,fi}$ [N]; $c_{min,fi}$ [mm]; $s_{min,fi}$ [mm]
Aspects of durability			
38	Durability	EAD 330008-04-0601 [1] 2.2.34	Description

EAD 330008-04-0601 [1] applies regarding the choice of the assessment method A1, A2, B and C of Table 2.1.1, rows 22 to 30. These assessment methods shall not be mixed.

2.2 Methods and criteria for assessing the performance of the product in relation to essential characteristics of the product

This chapter is intended to provide instructions for TABs. Therefore, the use of wordings such as “shall be stated in the ETA” or “it has to be given in the ETA” shall be understood only as such instructions for TABs on how results of assessments shall be presented in the ETA. Such wordings do not impose any obligations for the manufacturer, and the TAB shall not carry out the assessment of the performance in relation to a given essential characteristic when the manufacturer does not wish to declare this performance in the Declaration of Performance.

2.2.1 Characteristic fatigue resistance to steel failure of the whole system under shear load perpendicular (y) to the longitudinal (x) channel axis (bilinear function, assessment method C)

Determination of the characteristic fatigue resistance $\Delta V_{Rk,s,y,lo,n}$ for any steel failure of the whole system (anchor, connection anchor/channel, channel lips, channel bolt) with the characteristic lower load $V_{lok,s,y,n}$.

The type of loading is pulsating (same algebraic sign) or alternating (changing algebraic sign).

For the determination of the characteristic fatigue resistance the following steps for tests and assessments shall be carried out:

- Determination of the unfavourable loading position in accordance with Clause 2.2.1.1,
- Determination of the characteristic value of the reference static resistance in accordance with Clause 2.2.1.2 for the unfavourable loading position (in accordance with Clause 2.2.1.1),
- Determination of the unfavourable type of loading in accordance with Clause 2.2.1.3 for the unfavourable loading position (in accordance with Clause 2.2.1.1),
- Determination of the final characteristic fatigue resistance function in accordance with Clause 2.2.1.4 for the unfavourable loading position (in accordance with clause 2.2.1.1) and for the unfavourable type of loading (in accordance with Clause 2.2.1.3).

An overview about the assessment steps is given in the flowchart in Figure 2.2.1.1.

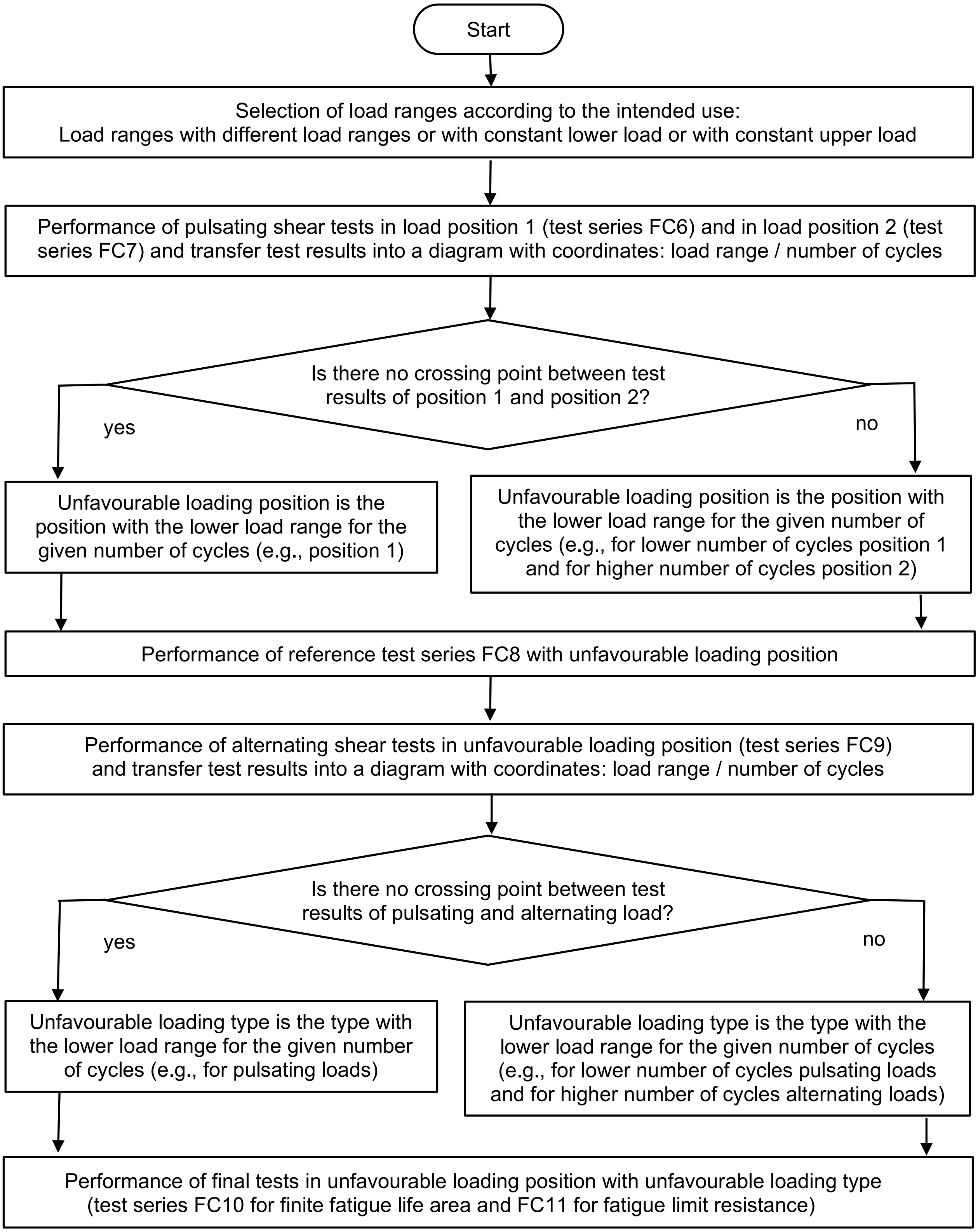


Figure 2.2.1.1: Flowchart for determination of characteristic fatigue steel resistance under shear load perpendicular (y) to the longitudinal (x) channel axis

2.2.1.1 Pre-tests for steel failure under pulsating shear perpendicular (y) to the longitudinal channel axis (Annex B, Table B.1.1, lines FC6 and FC7)

Determination of the unfavourable loading position for fatigue shear loading perpendicular (y) to the longitudinal (x) channel axis. The unfavourable loading position is defined as the one providing the lowest number of load cycles to failure for a given load level.

For the determination of the unfavourable loading position under perpendicular shear, pre-tests according to Annex B, Table B.1.1, lines FC6 and FC7, shall be performed. All channel bolts, channels, connection types, and anchor sizes with all materials and coatings specified by the manufacturer shall be tested.

Test conditions:

Six tests shall be performed in Position 1 according to Annex B, Figure B.3.1 and six tests shall be performed for Position 2 analogously.

The anchor channels shall be loaded in Position 1 (with the channel bolt position midway between the two anchors (test series FC6)) and Position 2 (with the channel bolt position over one anchor (test series FC7)) with a sinusoidal loading protocol until failure as shown in Figure 2.2.1.1.2. Loading positions are defined in Figure 2.2.1.1.1.

The tests shall be performed with different load ranges in the pulsating range with constant lower load close to zero or with different level of lower load (not zero) or with constant upper load (according to the intended use). The relevant loading procedure depends on the intended use of the fastenings, given by the manufacturer in its technical file (see clause 1.2.1).

Assessment:

Test results shall be transferred to coordinates as prescribed at Figures 2.2.1.1.3 and Figure 2.2.1.1.4 while checking whether resulting lines are crossing or not.

If the pre-test results do not show any crossing point between testing in Position 1 and Position 2 (see Figure 2.2.1.1.3), the final tests (test series FC10) and confirmation tests (test series FC11) shall be performed only in the unfavourable loading Position 1 or 2.

If the pre-test results show a crossing point between testing in Position 1 and Position 2 (see Figure 2.2.1.1.4), final tests (test series FC10) and confirmation tests (test series FC11) shall be performed in Position 1 and/or Position 2 depending on the location of the crossing point.

The unfavourable loading position is the position which gives the lowest load range and the lowest number of cycles.

The determination of the final bi-linear fatigue resistance function shall only take into account those test and pre-test results performed in the unfavourable loading position(s).

Further information on the testing and loading requirements is included in Clauses I.1, I.2.1 and I.2.2.

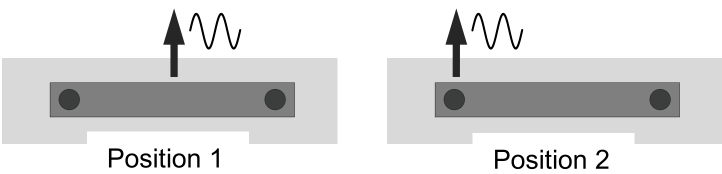
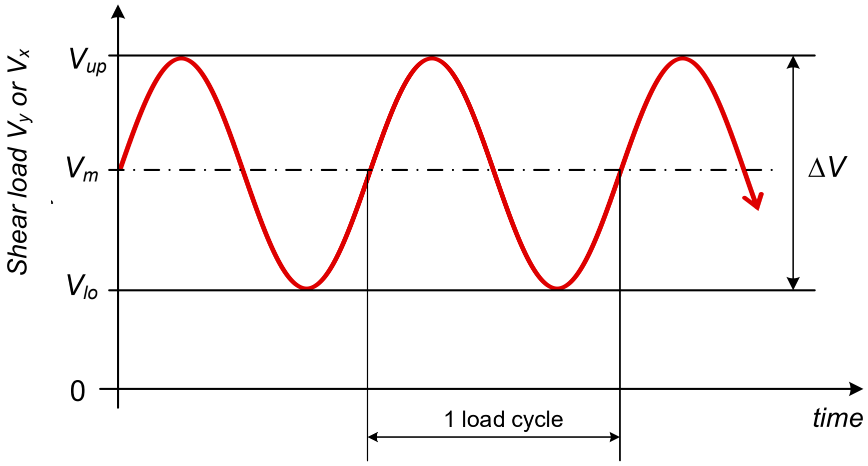


Figure 2.2.1.1.1: Loading position under fatigue shear perpendicular (y) to the longitudinal (x) channel axis (assessment method C)



V_x	shear load in direction of the longitudinal (x) channel axis
V_y	shear load perpendicular (y) to the longitudinal (x) channel axis
V_{up}	upper load level
V_{lo}	lower load level
V_m	mean value between upper load level and lower load level
ΔV	cyclic load range

Figure 2.2.1.1.2: Fatigue cyclic loading protocol under pulsating shear perpendicular (y) to the longitudinal channel axis or in the direction (x) of the longitudinal channel axis (assessment method C)

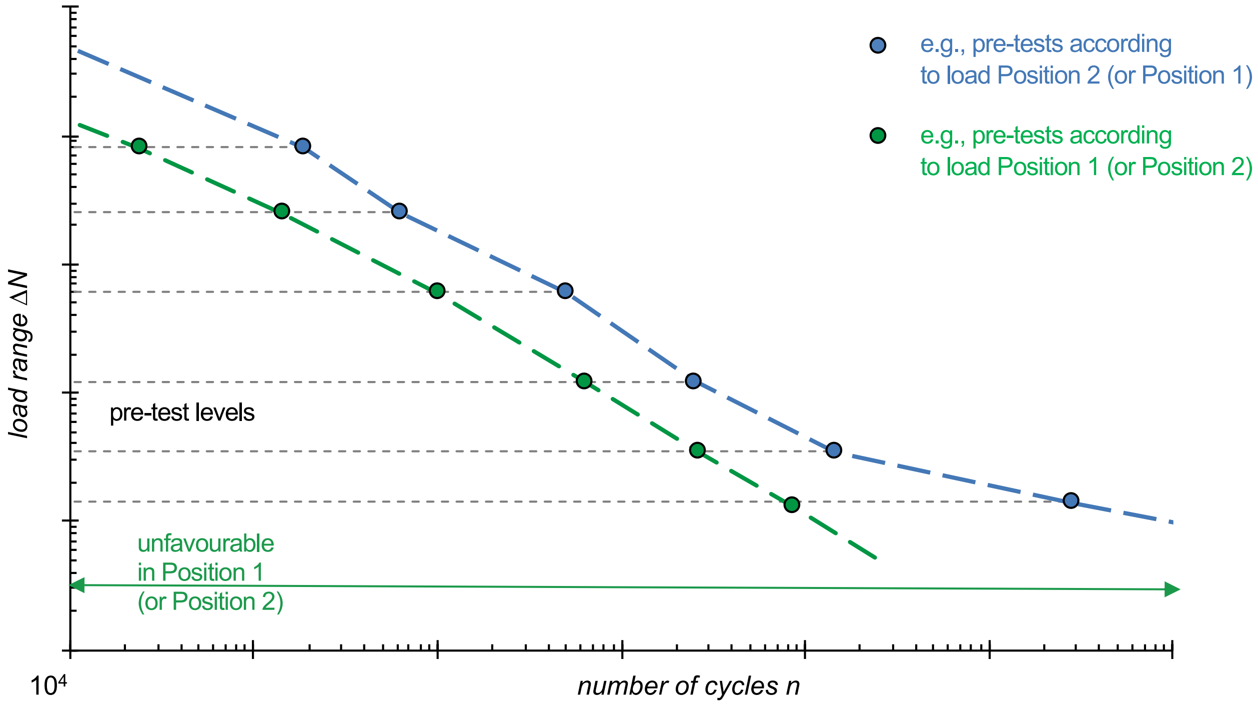


Figure 2.2.1.1.3: Example for the determination of the unfavourable loading position - no crossing observed during pre-testing in Position 1 and Position 2 (assessment method C)

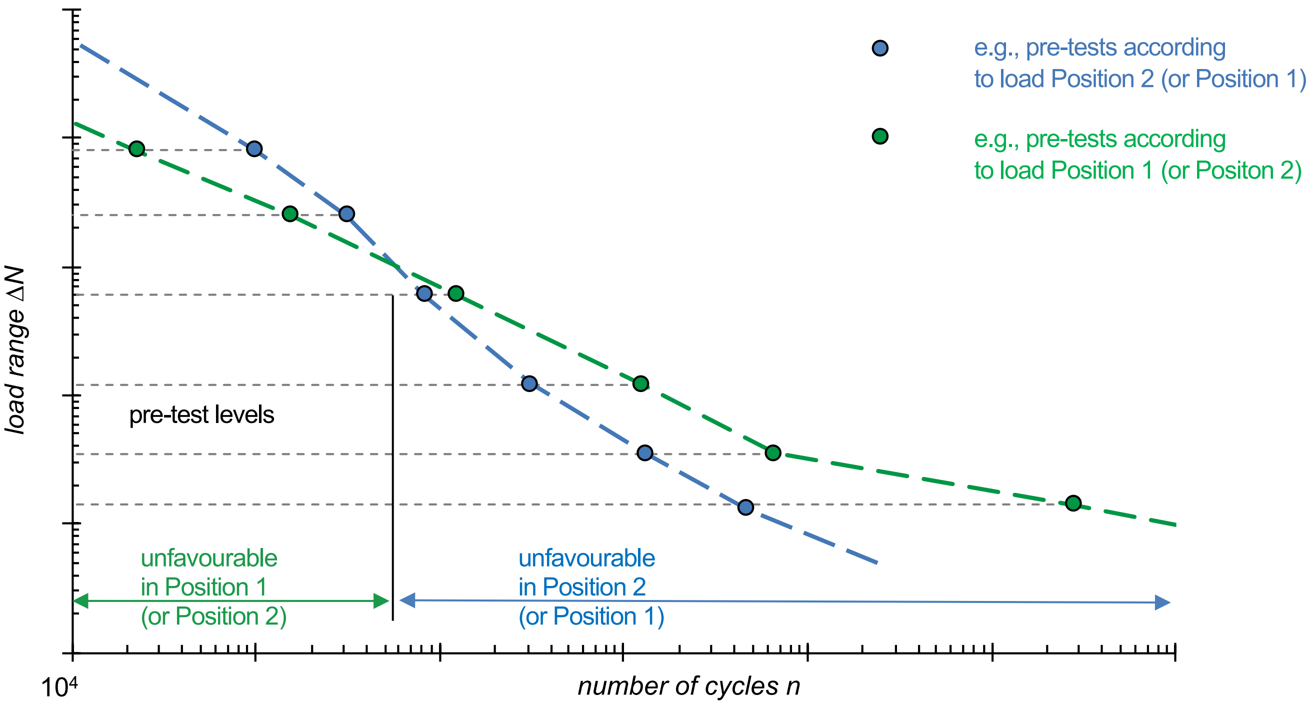


Figure 2.2.1.1.4: Example for the determination of the unfavourable loading position - crossing observed during pre-testing in Position 1 and Position 2 (assessment method C)

2.2.1.2 Reference tests for steel failure under shear perpendicular (y) to the longitudinal (x) channel axis (Annex B, Table B.1.1, line FC8)

Determination of the characteristic value of the reference static resistance for the unfavourable loading position under fatigue shear loading perpendicular (y) to the longitudinal (x) channel axis.

If the fatigue tests are performed with constant lower load close to zero, the reference tests shall not be performed.

If the fatigue tests are performed with certain level of lower load, testing in accordance with Annex B, Table B.1.1, line FC8, shall be performed. All channel bolts, channels, connection types, and anchor sizes with all materials and coatings specified by the manufacturer shall be tested.

Test conditions:

The anchor channels shall be loaded in the unfavourable loading position, as determined in pre-tests until failure. For the determination of the characteristic value of the reference static resistance at least three tests shall be performed

Assessment.

The characteristic value of the reference static resistance, $V_{k,y,ref,}$ shall be determined by statistical evaluation based on the 5%-quantile (5%-fractile) with a confidence level of 90%.

Further information on the testing and assessment is given in clause I.2.3.

The value of $V_{k,y,ref}$ shall be used to reduce the lower limit of fatigue cyclic loads in dependence on the actual static resistance of the test specimen (see Annex I, Equations (I.2.7.1a), (I.2.7.2a), (I.2.7.3a) and (I.2.7.4).

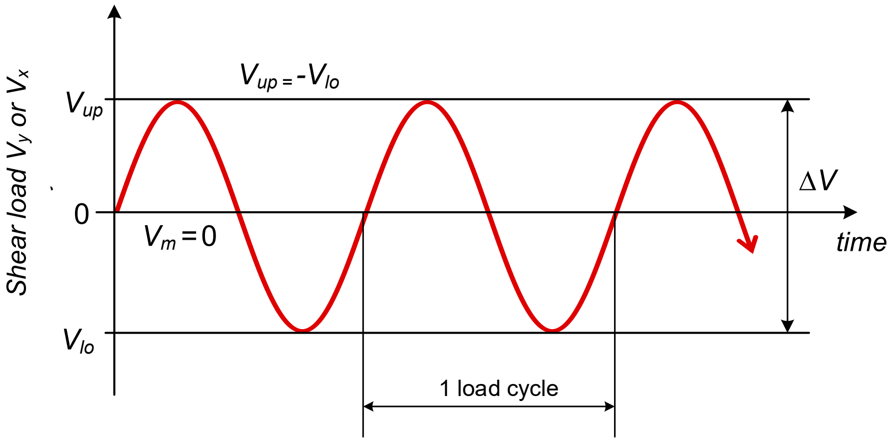
2.2.1.3 Pre-tests for steel failure under alternating shear perpendicular (y) to the longitudinal (x) channel axis (Annex B, Table B.1.1, line FC9)

Determination of the unfavourable type of loading for fatigue shear loading perpendicular (y) to the longitudinal (x) channel axis. The unfavourable type of loading is defined as the one providing the lowest number of load cycles to failure for a given load level.

For the determination of the unfavourable type of loading under perpendicular shear, alternating shear tests according to Annex B, Table B.1.1, line FC9, shall be performed. All channel bolts, channels, connection types, and anchor sizes with all materials and coatings specified by the manufacturer shall be tested.

Test conditions:

The anchor channels shall be loaded in the unfavourable loading position, as determined in pre-tests under pulsating shear perpendicular (y) to the longitudinal (x) channel axis, with a sinusoidal loading protocol as shown in Figure 2.2.1.3.1 until failure. Both positions shall be tested in case of crossing point according to figure 2.2.1.1.4, e.g., Pos.1 for lower number of cycles and Pos.2 for higher number of cycles



V_x shear load in direction of the longitudinal (x) channel axis

V_y shear load perpendicular (y) to the longitudinal (x) channel axis

V_{up} upper load level

V_{lo} lower load level

V_m mean value between upper load level and lower load level

ΔV cyclic load range

Figure 2.2.1.3.1: Fatigue cyclic loading protocol under alternating shear perpendicular (y) to the longitudinal channel axis or alternating shear in the direction (x) of the longitudinal channel axis (assessment method C)

The alternating shear loading shall be sinusoidal as shown in Figure 2.2.1.3.2 a) or approximated by two half-sinusoidal load cycles at the chosen frequency connected by a reduced speed, ramped load as shown in Figure 2.2.1.3.2 b). Both methods are equivalent.

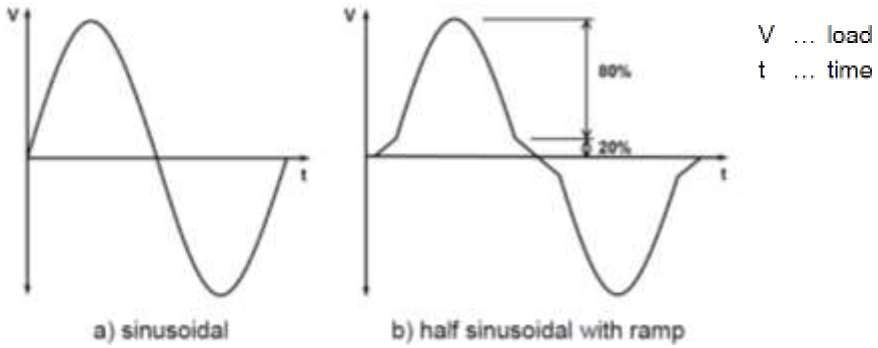


Figure 2.2.1.3.2: Permitted fatigue cyclic loading protocol for alternating shear tests (assessment method C)

The alternating shear tests shall be performed with the identical load ranges as in the pre-tests for the unfavourable loading position under pulsating shear load perpendicular (y) to the longitudinal (x) channel axis (see clause 2.2.1.1).

Assessment:

The results of the pre-tests under alternating shear load shall be used to determine the unfavourable type of loading for the final tests for steel failure.

The pre-test results under alternating shear load shall be compared with the results of the pre-tests under pulsating shear load obtained in the unfavourable loading position.

The confirmation of the pre-test results shall be performed in the same way as for the determination of the unfavourable loading position according to clause 2.2.1.1 “Pre-tests for steel failure under pulsating shear”:

If the pre-test results do not show any crossing point between testing of pulsating shear load and alternating shear load (analogously to Figure 2.2.1.1.3), the final tests (test series FC10) and confirmation tests (test series FC11) shall be performed only for the unfavourable loading type.

If the pre-test results show a crossing point between testing of pulsating shear load and alternating shear load (analogously to Figure 2.2.1.1.4), final tests (test series FC10) and confirmation tests (test series FC11) shall be performed for pulsating and/or for alternating shear load depending on the location of the crossing point.

The unfavourable type of loading is the type of loading which gives the lowest load range and the lowest number of cycles.

The determination of the final bi-linear fatigue resistance function shall only take into account those test and pre-test results performed for the unfavourable type of loading.

Further information on the testing and loading requirements is included in Clauses I.1, I.2.1 and I.2.4.

2.2.1.4 Final tests for steel failure under shear perpendicular (y) to the longitudinal (x) channel axis (Annex B, Table B.1.1, lines FC10 and FC11)

Determination of the final characteristic fatigue resistance function for any steel failure of the whole system (anchor, connection anchor/channel, channel lips, channel bolt) as a bilinear function of the number of load cycles, *n*.

For the determination of the finite life fatigue resistance under shear load perpendicular (y) to the longitudinal (x) channel axis, testing in accordance with Annex B, Table B.1.1 (assessment method C, test series FC10) shall be performed.

If the characteristic value is calculated on the safe side at $n = 10^8$ cycles in accordance with clause I.2.5, for the confirmation of the fatigue limit resistance under shear load tests shall not be performed. Otherwise, the fatigue limit resistance shall be assessed by tests according to Annex B, Table B.1.1, assessment method C, test series FC11 (see Annex I, Figure I.2.6.1).

All channel bolts, channels, connection types, and anchor sizes with all materials and coatings specified by the manufacturer shall be tested and assessed.

Test conditions:

The anchor channels shall be loaded in the unfavourable loading position and type of loading, as determined in pre-tests with a sinusoidal load process.

The number of cycles to failure, *n*, for each range of force ΔV_y (see Clause I.2.5) shall be determined through testing. All test results, which belong to the unfavourable loading position and load direction shall be used for the determination of the fatigue resistance function.

Assessment:

The characteristic fatigue resistance function shall be determined by statistical evaluation according to Clause I.2.5 based on the 5%-quantile with a confidence level of 90% (Example see Figure 2.2.1.4.1 (Method C)).

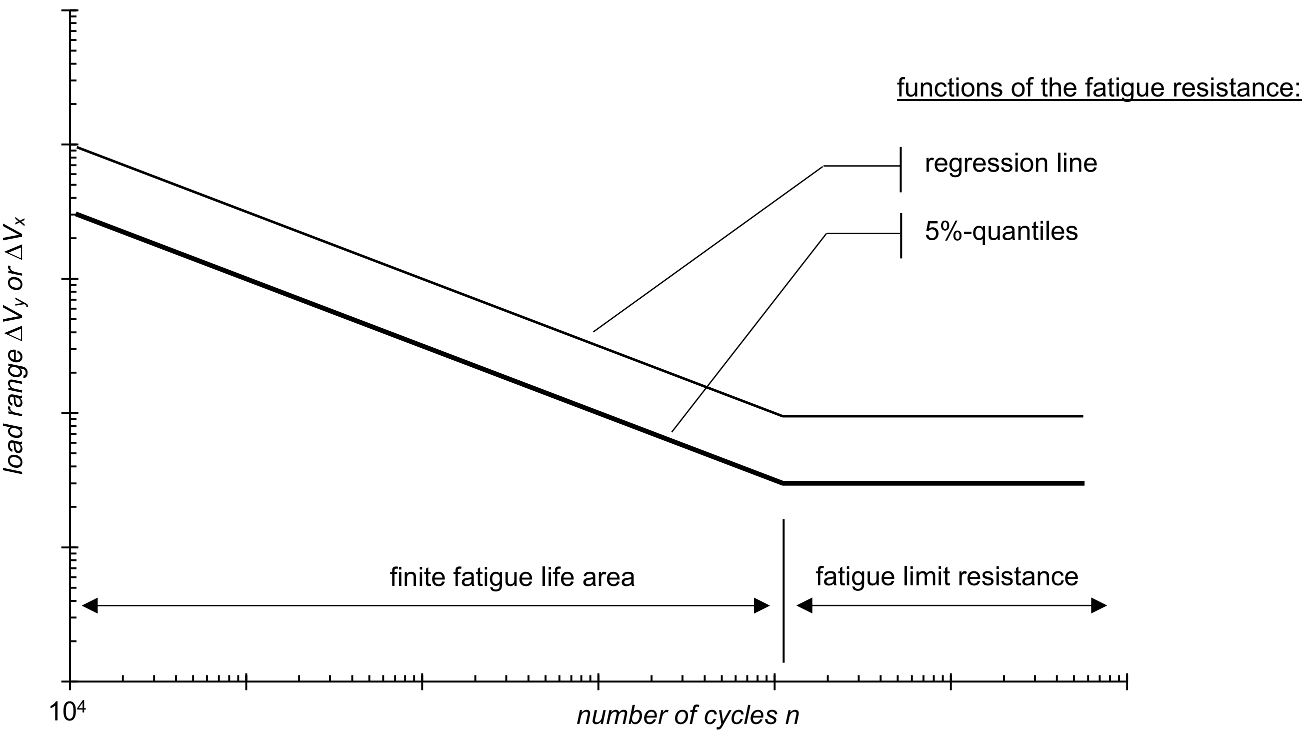


Figure 2.2.1.4.1: Example of characteristic fatigue resistance function (assessment method C)

The characteristic fatigue resistance $\Delta V_{Rk,s,y,lo,n}$ given for *n* load cycles is dependent on the characteristic value of lower load level $V_{lok,s,y,n}$. If alternating loads are the unfavourable type of loading than $V_{lok,s,y,n}$ = 0.

Detailed information on the testing and assessment is included in Clauses I.1, I.2.1, I.2.5, I.2.6 and I.2.7.

All the relevant information regarding the assessment of the fatigue resistance function (at least functions of the regression line and characteristic fatigue resistance, confirmation of fatigue limit resistance, confirmation of characteristic lower load) shall be recorded.

Expression of results:

$\Delta V_{Rk,s,y,lo,n}$, $V_{lok,s,y,n}$ [N] (n = 10^4 to n = ∞)

2.2.2 Characteristic fatigue resistance to steel failure of the whole system under shear load in the direction (x) of the longitudinal (x) channel axis (bilinear function, assessment method C)

Determination of the characteristic fatigue resistance $\Delta V_{Rk,s,x,lo,n}$ for any steel failure of the whole system (anchor, connection anchor/channel, connection channel bolt/channel, channel bolt) with the characteristic lower load $V_{lok,s,x,n}$.

The type of loading is pulsating (same algebraic sign) or alternating (changing algebraic sign).

For the determination of the characteristic fatigue resistance the following steps for tests and assessments shall be carried out:

- Determination of the unfavourable loading position in accordance with Clause 2.2.2.1,
- Determination of the characteristic value of the reference static resistance in accordance with Clause 2.2.2.2 for the unfavourable loading position (in accordance with Clause 2.2.2.1),
- Determination of the unfavourable type of loading in accordance with Clause 2.2.2.3 for the unfavourable loading position (in accordance with Clause 2.2.2.1),
- Determination of the final characteristic fatigue resistance function in accordance with Clause 2.2.2.4 for the unfavourable loading position (in accordance with clause 2.2.2.1) and for the unfavourable type of loading (in accordance with Clause 2.2.2.3).

An overview about the assessment steps is given in the flowchart in Figure 2.2.2.1.

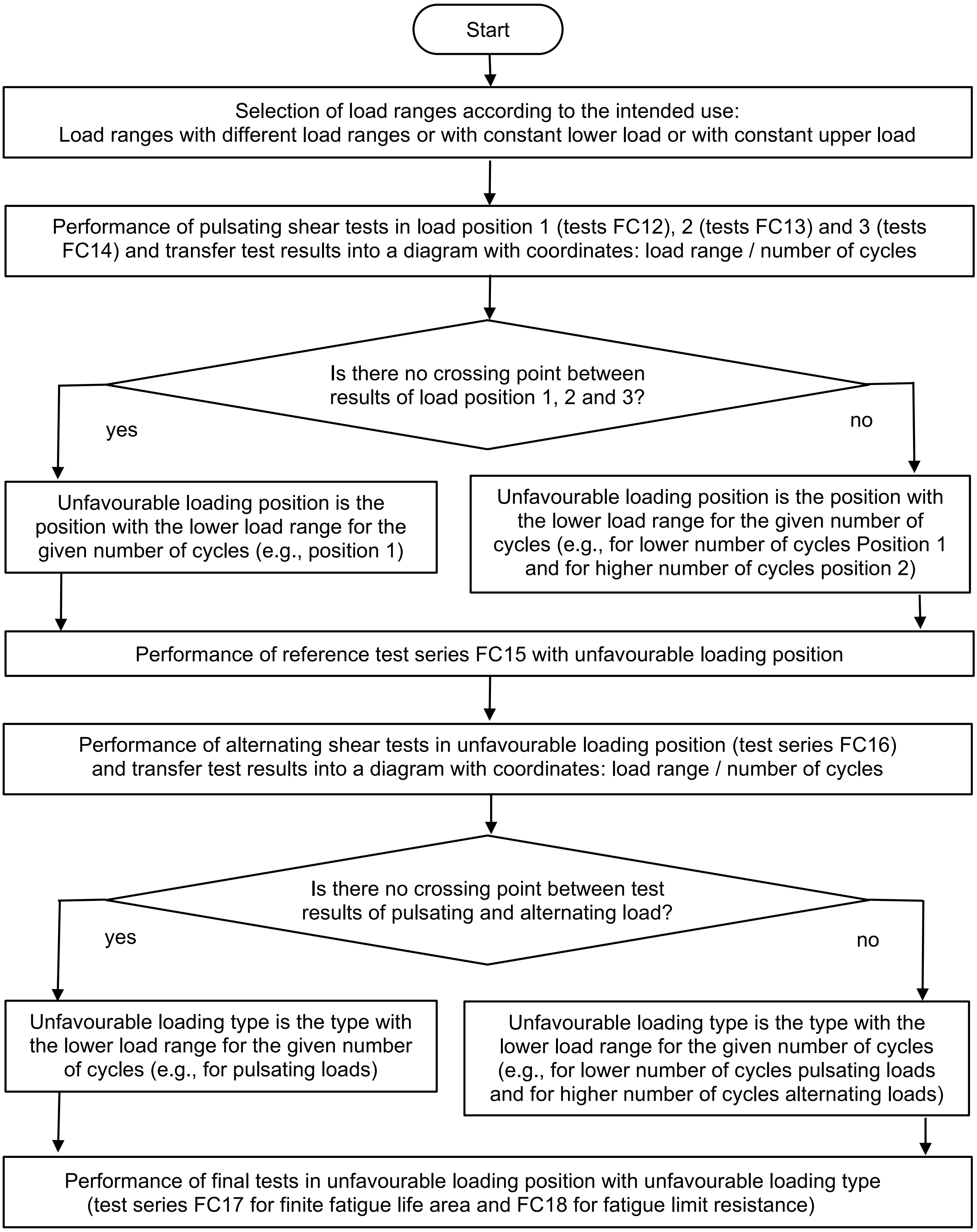


Figure 2.2.2.1: Flowchart for determination of characteristic fatigue steel resistance under shear load in direction (x) of the longitudinal (x) channel axis

2.2.2.1 Pre-tests for steel failure under pulsating shear in the direction (x) of the longitudinal channel axis (Annex B, Table B.1.1, lines FC12, FC13, FC14)

Determination of the unfavourable loading position for fatigue shear loading in the direction of the longitudinal (x) channel axis. The unfavourable loading position is defined as the one providing the lowest number of load cycles to failure for a given load level.

For the determination of the unfavourable loading position under longitudinal shear, pre-tests according to Annex B, Table B.1.1, lines FC12, FC13 and FC14, shall be performed. All channel bolts, channels, connection types, and anchor sizes with all materials and coatings specified by the manufacturer shall be tested.

<u>Test conditions:</u>

The tests shall be performed according to Annex B, clause B.3.

The anchor channels shall be loaded in Position 1 (test series FC12), Position 2 (test series FC13) and Position 3 (test series FC14) according to Figure 2.2.2.1.1 with a sinusoidal loading protocol until failure as shown in Figure 2.2.1.1.2.

The tests shall be performed with different load ranges in the pulsating range with constant lower load close to zero or with different level of lower load (not zero) or with constant upper load (according to the intended use). The relevant loading procedure depends on the intended use of the fastenings, given by the manufacturer in its technical file (see clause 1.2.1).

<u>Assessment:</u>

The confirmation of the pre-test results shall be performed in the same way as for the determination of the unfavourable loading position according to clause 2.2.1.1 "Pre-tests for steel failure under pulsating shear".

Further information on the testing and loading requirements is included in Clause I.1.2.2.

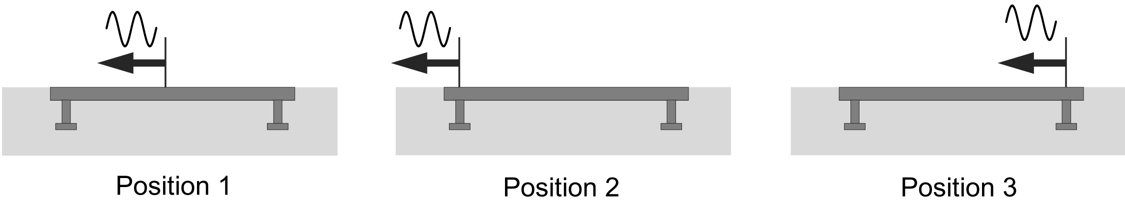


Figure 2.2.2.1.1: Loading position under fatigue shear in the direction (x) of the longitudinal channel axis (assessment method C)

2.2.2.2 Reference tests for steel failure under shear in the direction (x) of the longitudinal channel axis (Annex B, Table B.1.1, line FC15)

Determination of the characteristic value of the reference static resistance for the unfavourable loading position under fatigue shear loading in the direction of the longitudinal (x) channel axis.

If the fatigue tests are performed with constant lower load close to zero, the reference tests shall not be performed.

If the fatigue tests are performed with certain level of lower load, testing in accordance with Annex B, Table B.1.1, line FC15, shall be performed. All channel bolts, channels, connection types, and anchor sizes with all materials and coatings specified by the manufacturer shall be tested.

<u>Test conditions:</u>

The anchor channels shall be loaded in the unfavourable loading position, as determined in pre-tests until failure. For the determination of the characteristic value of the reference static resistance at least three tests shall be performed.

Assessment:

The characteristic value of the reference static resistance, $V_{k,x,ref,}$ shall be determined by statistical evaluation based on the 5%-quantile (5%-fractile) with a confidence level of 90%.

Further information on the testing and assessment is given in clause I.1.2.3. The value of $V_{k,x,ref}$ shall be used to reduce the lower limit of fatigue cyclic loads in dependence on the actual static resistance of the test specimen (see Annex I, Equations (I.2.7.1b), (I.2.7.2b), (I.2.7.3b) and (I.2.7.4)).

2.2.2.3 Pre-tests for steel failure under alternating shear in the direction (x) of the longitudinal channel axis (Annex B, Table B.1.1, line FC16)

Determination of the unfavourable type of loading for fatigue shear loading in the direction of the longitudinal (x) channel axis. The unfavourable type of loading is defined as the one providing the lowest number of load cycles to failure for a given load level.

For the determination of the unfavourable type of loading under longitudinal shear, alternating shear tests according to Annex B, Table B.1.1, line FC16, shall be performed. All channel bolts, channels, connection types, and anchor sizes with all materials and coatings specified by the manufacturer shall be tested.

Test conditions:

The anchor channels shall be loaded in the unfavourable loading position, as determined in pre-tests under pulsating shear in the direction of the longitudinal (x) channel axis, with a sinusoidal or sinusoidal approximated load process according to Figure 2.2.1.3.1 until failure.

The alternating shear tests shall be performed with the identical load ranges as in the pre-tests for the unfavourable loading position under pulsating shear load in the direction of the longitudinal (x) channel axis (see Clause 2.2.1.1).

Assessment:

The results of the pre-tests under alternating shear load shall be used to determine the unfavourable type of loading for the final tests for steel failure.

The pre-test results under alternating shear load shall be compared with the results of the pre-tests under pulsating shear load obtained in the unfavourable loading position.

The confirmation of the pre-test results shall be performed in the same way as for the determination of the unfavourable loading position according to clause 2.2.1.1 “Pre-tests for steel failure under pulsating shear”.

If the pre-test results do not show any crossing point between testing of pulsating shear load and alternating shear load (analogously to Figure 2.2.1.1.3), the final tests (test series FC17) and confirmation tests (test series FC11) shall be performed only for the unfavourable loading type.

If the pre-test results show a crossing point between testing of pulsating shear load and alternating shear load (analogously to Figure 2.2.1.1.4), final tests (test series FC10) and confirmation tests (test series FC18) shall be performed for pulsating and/or for alternating shear load depending on the location of the crossing point.

The unfavourable type of loading is the type of loading which gives the lowest load range and the lowest number of cycles.

The determination of the final bi-linear fatigue resistance function shall only take into account those test and pre-test results performed for the unfavourable type of loading.

Further information on the testing and loading requirements is included in Clause I.1.2.4.

2.2.2.4 Final tests for steel failure under shear in the direction (x) of the longitudinal channel axis (Annex B, Table B.1.1, lines FC17 and FC18)

Determination of the final characteristic fatigue resistance function for any steel failure of the whole system (anchor, connection anchor/channel, connection channel bolt/channel, channel bolt) as a bilinear function of the number of load cycles, *n*.

For the determination of the finite life fatigue resistance under shear load in the direction of the longitudinal (x) channel axis, testing in accordance with Annex B, Table B.1.1 (assessment method C, test series FC17) shall be performed.

If the characteristic value is calculated on the safe side at $n = 10^8$ cycles in accordance with clause I.2.5, for the confirmation of the fatigue limit resistance under shear load in the direction of the longitudinal (x) channel axis tests shall not be performed. Otherwise, the fatigue limit resistance shall be evaluated by tests according to Annex B, Table B.1.1, assessment method C, test series FC18 (see Annex I, Figure I.2.6.1).

All channel bolts, channels, connection types, and anchor sizes with all materials and coatings specified by the manufacturer shall be tested and assessed.

Test conditions:

The anchor channels shall be loaded in the unfavourable loading position and type of loading, as determined in pre-tests with a sinusoidal load process.

The number of cycles to failure, *n*, for each range of force ΔV_x (see Clause I.2.5) shall be determined through testing. All test results, which belong to the unfavourable loading position shall be used for the determination of the fatigue resistance function.

Assessment:

The characteristic fatigue resistance function shall be determined by statistical evaluation according to Clause I.2.5 based on the 5%-quantile with a confidence level of 90% (Example see Figure 2.2.1.4.1 (Method C)).

The characteristic fatigue resistance $\Delta V_{Rk,s,x,lo,n}$ given for *n* load cycles is dependent on the characteristic value of lower load level $V_{lok,s,x,n}$. If alternating loads are the unfavourable type of loading than $V_{lok,s,x,n}$ = 0.

Detailed information on the testing and assessment is included in Clauses I.1, I.2.1, I.2.5, I.2.6 and I.2.7.

All relevant information regarding the assessment of the fatigue resistance function (i.e., functions of the regression line and characteristic fatigue resistance, confirmation of fatigue limit resistance, confirmation of characteristic lower load, etc.) shall be recorded.

Expression of results:

$\Delta V_{Rk,s,x,lo,n}$, $V_{lok,s,x,n}$ [N] (n = 10^4 to n = ∞)

2.2.3 Characteristic fatigue resistance to concrete pry-out failure under shear load perpendicular (y) to the longitudinal (x) channel axis and in the direction (x) of the longitudinal channel axis (bilinear function, assessment method C)

Determination of the characteristic fatigue resistance $\Delta V_{Rk,cp,E,n}$ for concrete pry-out failure under cyclic shear loading for both directions (perpendicular (y) to the longitudinal (x) channel axis and in the direction of the longitudinal (x) channel axis).

The characteristic fatigue resistance to concrete pry-out failure as a function of the number of cycles, *n*, shall be calculated as follows:

$$\Delta V_{Rk,cp,y,E,n} = \eta_{k,cp,Vy,fat} \cdot V_{Rk,cp} \quad \text{[N]} \qquad (2.2.3.1a)$$

$$\Delta V_{Rk,cp,x,E,n} = \eta_{k,cp,Vx,fat} \cdot V_{Rk,cp} \quad \text{[N]} \qquad (2.2.3.1b)$$

$$\eta_{k,cp,Vy,fat} = 1 + 0{,}125 \cdot lg\, n \cdot \left(Y_y - 1\right) - S_{y,lok} \quad \text{for } 1 \cdot 10^4 \leq n \leq 1 \cdot 10^8 \qquad (2.2.3.2a)$$

$$\left(Y_y - S_{y,lok}\right) \cdot 10^{\frac{(Y_y - 1)\cdot((lg\, n) - 8)}{8 \cdot (\ln 10) \cdot (Y_y - S_{y,lok})}} \quad \text{for } n > 1 \cdot 10^8 \qquad (2.2.3.3a)$$

$$\eta_{k,cp,Vx,fat} = 1 + 0{,}125 \cdot lg\, n \cdot (Y_x - 1) - S_{x,lok} \quad \text{for } 1 \cdot 10^4 \leq n \leq 1 \cdot 10^8 \qquad (2.2.3.2b)$$

$$\left(Y_x - S_{x,lok}\right) \cdot 10^{\frac{(Y_x - 1)\cdot((lg\, n) - 8)}{8 \cdot (\ln 10) \cdot (Y_x - S_{x,lok})}} \quad \text{for } n > 1 \cdot 10^8 \qquad (2.2.3.3b)$$

where:

$V_{Rk,cp}$ characteristic value of static resistance to concrete pry-out failure according to EN 1992-4, Equation (7.76a)

with

$$Y_y = \frac{0{,}45 + 1{,}8 \cdot S_{y,lok}}{1 + 1{,}8 \cdot S_{y,lok} - 0{,}3 \cdot S_{y,lok}^2} \qquad (2.2.3.4a)$$

$$S_{y,lok} = 2{,}25 \cdot V_{y,Elok} / V_{Rk,cp} \leq 0{,}8 \qquad (2.2.3.5a)$$

and

$$Y_x = \frac{0{,}45+1{,}8\cdot S_{x,lok}}{1+1{,}8\cdot S_{x,lok}-0{,}3\cdot S_{x,lok}^2} \quad (2.2.3.4b)$$

$$S_{x,lok} = 2{,}25 \cdot V_{x,Elok}/V_{Rk,cp} \leq 0{,}8 \quad (2.2.3.5b)$$

$V_{y,Elok}$ or $V_{x,Elok}$ characteristic lower cyclic shear load on the anchor (for pulsating shear loads) perpendicular (y) to the longitudinal (x) channel axis or in the direction of the longitudinal (x) channel axis

$V_{y,Elok}$ or $V_{x,Elok}$ = 0 (for alternating shear loads)

lg n = $\log_{10}$ n = decadic logarithm of n (with n = number of cycles)

ln 10 = $\log_e$ 10 = natural logarithm of 10

Expression of results:

$\Delta V_{Rk,cp,y,E,n}$, $\Delta V_{Rk,cp,x,E,n}$ [N] (n = 10^4 to n = ∞)

2.2.4 Characteristic fatigue resistance to steel failure of the whole system under combined fatigue tension and shear load (bilinear function, assessment method C)

Determination of the exponent for calculation of characteristic fatigue resistance according to EOTA TR 050 [2], Table 3.6, for any steel failure of the whole system under combined tension and shear loading.

For steel failure under combined tension and shear loading the following exponents shall be given on the safe side:

$k_{sn} = 0{,}5$ for channel bolts with thread diameter smaller than M16

$k_{sn} = 0{,}7$ for channel bolts with thread diameter M16 and larger

where:

k_{sn} exponent for calculation of steel failure

Currently, no tests are available to determine more favourable values of k_{sn}.

Expression of results:

k_{sn} [-]

3 ASSESSMENT AND VERIFICATION OF CONSTANCY OF PERFORMANCE

3.1 System of assessment and verification of constancy of performance to be applied

EAD 330008-04-0601 [1] applies.

3.2 Tasks of the manufacturer

EAD 330008-04-0601 [1], clause 3.2, applies with the following amendments.

Additionally, the cornerstones of the actions to be undertaken by the manufacturer of anchor channels in the procedure of assessment and verification of constancy of performance are laid down in Table 3.2.1

Table 3.2.1 Control plan for the manufacturer; cornerstones

No	Subject/type of control	Test or control method	Criteria, if any	Min. number of samples	Minimum frequency of control
Factory production control (FPC) [including testing of samples taken at the factory in accordance with a prescribed test plan]					
1	Characteristic steel fatigue resistance for shear for assessment method C	Shear tests under different fatigue cyclic load levels 1) 2)	3)	3 perpendicular shear tests 3 longitudinal shear tests (1 per load level)	1 size per year and all sizes, types and materials in 5 years

1) Tests shall be performed in the unfavourable loading position with the smallest channel bolt.

2) The conditions of tests shall be performed according to Annex B, clause B.3 with the same level of lower or upper load as for the assessment tests. The load ranges are determined as follow:

Load level a: characteristic steel resistance given in the ETA for $n = 10^4$

Load level b: characteristic steel resistance given in the ETA for $n = 10^5$

Load level c: characteristic steel resistance given in the ETA for $n = 10^6$

3) The constancy of performance is verified if the number of cycles to failure is greater than those for the appropriate characteristic resistance. The specimens shall be tested to failure or until reaching $2 \cdot 10^6$ number of cycles.

3.3 Tasks of the notified body

EAD 330008-04-0601 [1], clause 3.3, applies.

4 REFERENCE DOCUMENTS

EAD 330008-04-0601 [1], clause 4, applies with the following amendments.

[1] EAD 330008-04-0601	Anchor channels
[2] EOTA TR 050:2023-10	Technical Report 050, "Calculation Method for the Performance of Anchor Channels under fatigue loads"

ANNEX A: RESISTANCE UNDER STATIC AND QUASI-STATIC LOADING – GENERAL ASPECTS OF TESTS AND ASSESSMENT

EAD 330008-04-0601 [1], Annex A, applies.

ANNEX B: RESISTANCE UNDER FATIGUE CYCLIC TENSION AND SHEAR LOADING – GENERAL ASPECTS OF TESTS

B.1 Test programme for resistances under fatigue cyclic tension and shear load

Tables B.1.1 to B.1.3 of EAD 330008-04-0601 [1] apply for tension.

Additionally, Table B.1.1 of this EAD applies for shear.

Table B.1.1: Tests under fatigue cyclic shear loading: assessment method C

N°	Tests according to the clauses referenced below	Concrete	Loading position	Type of loading [5)]	Minimum number of tests	Channel size	Anchor size	Anchor channel material	Anchor channel coating	Connection anchor/channel	Channel bolt diameter	Channel bolt material	Channel bolt coating
	Steel failure under shear load acting perpendicular (y) to the longitudinal (x) channel axis												
FC6	2.2.1.1 Pre-tests unfavourable position of the load subject to the number of cycles	C20/25	Position 1	pulsating	6 [1)]	all	all	all	all	all	all	all	all
FC7		C20/25	Position 2		6 [1)]	all	all	all	all	all	all	all	all
FC8	2.2.1.2 Reference tests for any steel failure of the whole system [2)]	C20/25	Position 1 and/or Position 2	static	3	all	all	all	all	all	all	all	all
FC9	2.2.1.3 Pre-tests unfavourable type of loading subject to the number of cycles	C20/25	Position 1 and/or Position 2	alternating	6	all	all	all	all	all	all	all	all
FC10	2.2.1.4 Final tests for any steel failure of the whole system	C20/25	Position 1 and/or Position 2	both	16	all	all	all	all	all	all	all	all
FC11		C20/25			4 [3)]	all	all	all	all	all	all	all	all
	Steel failure under shear load acting in the direction (x) of the longitudinal (x) channel axis												
FC12	2.2.2.1 Pre-tests unfavourable position of the load subject to the number of cycles	C20/25	Position 1	pulsating	6 [1), 4)]	all	all	all	all	all	all	all	all
FC13		C20/25	Position 2		6 [1)]	all	all	all	all	all	all	all	all
FC14		C20/25	Position 3		6 [1), 4)]	all	all	all	all	all	all	all	all
FC15	2.2.2.2 Reference tests for any steel failure of the whole system [2)]	C20/25	Position 1, Position 2 and/or Position 3	static	3	all	all	all	all	all	all	all	all
FC16	2.2.2.3 Pre-tests unfavourable type of loading subject to the number of cycles	C20/25	Position 1, Position 2 and/or Position 3	alternating	6	all	all	all	all	all	all	all	all
FC17	2.2.2.4 Final tests for any steel failure of the whole system	C20/25	Position 1, Position 2 and/or Position 3	both	16	all	all	all	all	all	all	all	all
FC18		C20/25			4 [3)]	all	all	all	all	all	all	all	all

1) Results of the pre-tests performed on the unfavourable (decisive) loading position shall be used in combination with the final tests for steel failure.

2) If the fatigue tests are performed with constant lower load close to zero, the reference tests shall not be performed.

3) If the characteristic value is calculated on the safe side at n = 10^8 cycles, for the confirmation of the fatigue limit resistance tests shall not be performed.

4) If steel failure of connection between channel lips and channel bolt or steel failure of channel bolt is observed, the minimum number of tests shall be reduced to n = 3.

5) pulsating = pulsating load
alternating = alternating load
both = pulsating and/or alternating load
static = static load

B.2 Test details for resistances under fatigue cyclic tension loading

EAD 330008-04-0601 [1] applies for tension.

B.3 Test details for resistances under fatigue cyclic shear loading

The same test conditions as in clause B.2 shall be applied analogues for shear with V_x or V_y substitutes N.

Additionally, for assessment method C the tests for steel failure under shear load shall also be carried out on anchor channels with two anchors cast in uncracked concrete (see EAD 330008-04-0601 [1], Annex B, Figure B.2.1). The edge distances shall be large enough to avoid an edge influenced failure by cracks in the concrete specimens. In tests under shear load in the direction of the longitudinal (x) channel axis, the gap between the loaded end of the channel profile and the concrete shall be at least 10 mm to ensure that the forces are transmitted only by the anchors.

The shear tests shall be performed only for applications with general contact according to EAD 330008-04-0601 [1], Figure 1.2.1.2 a). A friction-reducing layer (e.g., polytetrafluoroethylene) shall be placed over the entire contact area between fixture and concrete surface as well as between fixture and channel profile. The re-application of installation torque shall correspond to finger-tight conditions in the range of 5 Nm ≤ 0,1 $T_{inst,g}$ ≤ 50 Nm.

The shear load ΔV shall be applied via the channel bolt to the anchor channel parallel to the concrete surface. The thickness of the fixture in the immediate vicinity of the tested anchor channel shall be equal to or greater than the diameter of the used channel bolt ($t_{fix} \geq d$). Lift-up of the fixture due to a displacement of the anchor channel shall not be restraint.

The diameter of the clearance hole in the fixture shall be taken according to EN 1992-4, Table 6.1, respectively, EAD 330008-04-0601 [1], Annex A, Table A.2.2.3.1.

The test setup shall include moment hinges at two positions to avoid eccentricities at the point of load introduction (see Figure B.3.2). An example for the load application and displacement measurement without influence of deformation of the test rig is given in Figure B.3.1.

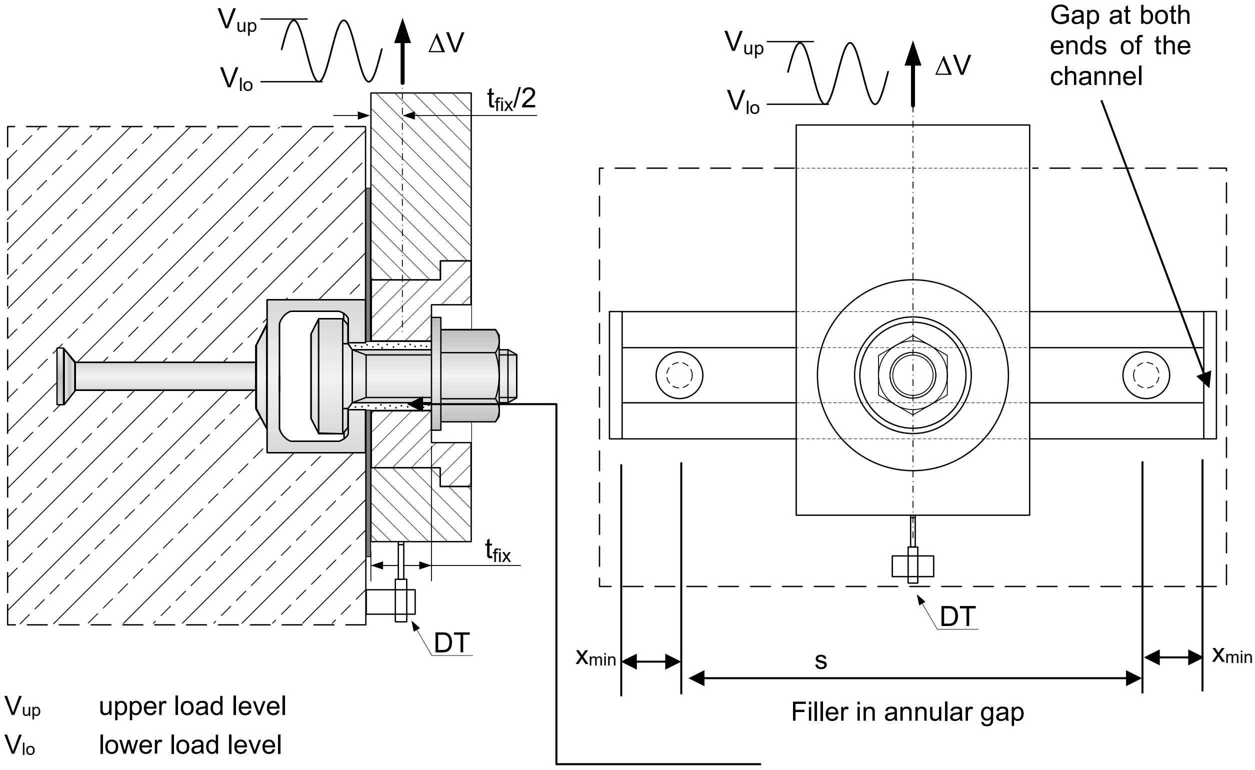
In alternating shear tests the load shall be controlled in accordance with Figure 2.2.1.3.1. Testing frequency shall be between 0,1 Hz and 10 Hz.

The number of cycles to failure and the failure mode shall be recorded for the fatigue shear tests. In addition, the following values shall be continuously recorded:

- Displacements corresponding to the maximum and minimum load as a function of the number of load cycles *n,*
- Elapsed time and number of load cycles,
- $V_{y,lo}$ or $V_{x,lo}$ and s_{lo} (minimum force and corresponding displacement),
- $V_{y,up}$ or $V_{x,up}$ and s_{up} (maximum force and corresponding displacement),
- Loosening of the nut or channel bolt shall be monitored during testing.

In the alternating shear tests, the displacements as a function of the applied load shall be plotted additionally, in the form of hysteresis loops at specified numbers of load cycles.

Loosening of the nut or channel bolt shall not occur during testing, otherwise the anchor channel shall not be assessed according to this EAD.



V_{up} upper load level
V_{lo} lower load level
ΔV cyclic load range
DT displacement transducer
t_{fix} thickness of fixture made of steel, which stays elastic over the whole test

Figure B.3.1: Example of test setup for steel failure under shear load in Position 1 (perpendicular (y) to the longitudinal (x) channel axis)

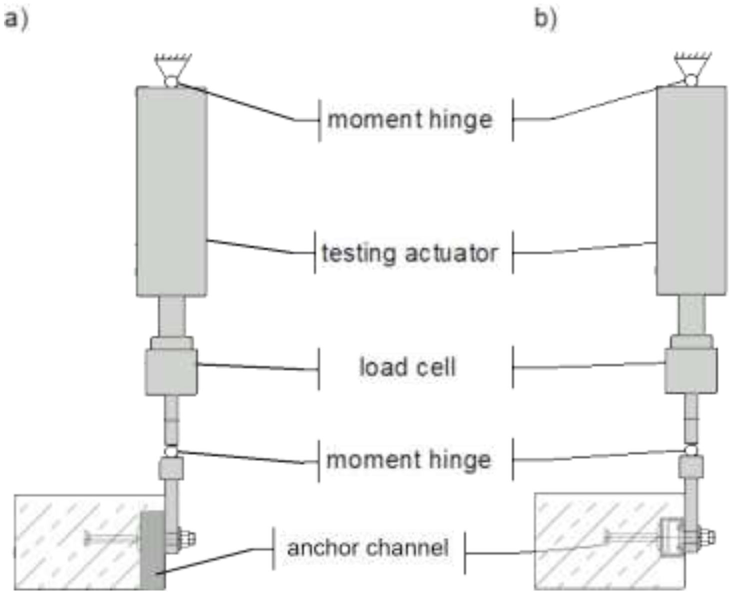


Figure B.3.2: Examples of test setups including two moment hinges for shear in the direction of longitudinal axis of the channel a) and shear perpendicular to the longitudinal axis of the channel b)

ANNEX C: RESISTANCE UNDER FATIGUE CYCLIC TENSION LOADING – ASSESSMENT: INTERACTIVE METHOD (METHOD A1)

EAD 330008-04-0601 [1], Annex C, applies.

ANNEX D: RESISTANCE UNDER FATIGUE CYCLIC TENSION LOADING – ASSESSMENT: TRI-LINEAR FUNCTION (METHOD A2)

EAD 330008-04-0601 [1], Annex D, applies.

ANNEX E: RESISTANCE UNDER FATIGUE CYCLIC TENSION LOADING – ASSESSMENT: CHARACTERISTIC FATIGUE LIMIT RESISTANCE (METHOD B)

EAD 330008-04-0601 [1], Annex E, applies.

ANNEX F: TEST DETAILS AND ASSESSMENT OF ANCHOR CHANNELS IN CONCRETE CONCERNING RESISTANCE TO FIRE

EAD 330008-04-0601 [1], Annex F, applies.

ANNEX G: TEST DETAILS AND ASSESSMENT OF ANCHOR CHANNELS IN CONCRETE CONCERNING RESISTANCE TO SEISMIC LOADING (SEISMIC PERFORMANCE CATEGORY C1)

EAD 330008-04-0601 [1], Annex G, applies.

ANNEX H: RESISTANCE UNDER FATIGUE CYCLIC TENSION LOADING – ASSESSMENT: BI-LINEAR FUNCTION (METHOD C)

EAD 330008-04-0601 [1], Annex H, applies for tension.

ANNEX I: RESISTANCE UNDER FATIGUE CYCLIC SHEAR LOADING – ASSESSMENT: BI-LINEAR FUNCTION (METHOD C)

I.1 Basics

The force-controlled periodic loading with sinusoidal shape shall be used as the most disadvantageous case (practical application) of the test specimen.

The repeated loads consist of a lower load level and an upper load level with same algebraic sign (pulsating shear actions) and changing algebraic sign (alternating shear actions) and shall be applied on the specimen until fatigue failure or a limit number of cycles is reached.

Testing in the pulsating range shall be performed either for the determination of the characteristic fatigue resistance with origin load ($V_{y,lok,s,n}$ = 0 and $V_{x,lok,s,n}$ = 0) or the characteristic fatigue resistance with other chosen values for either the lower or upper load ($V_{y,lok,s,n}$ > 0 and $V_{x,lok,s,n}$ > 0). The assessment of the fatigue resistance considers also tests in the alternating range with lower and upper load of different algebraic sign.

The method is based on the assumption that the fatigue resistance function according to Figure 2.2.1.4.1 in the finite fatigue life area can be described by a straight line when using logarithmic scaling for abscissa (number of cycles n) and ordinate (range of force ΔV_y *and* ΔV_x). The upper level of the line is the fatigue resistance at $n = 10^4$ load cycles. The lower horizontal level represents the fatigue limit resistance for infinite number of cycles ($n = \infty$).

Tests which are stopped without failure shall not be included in the final confirmation of the fatigue resistance in the finite fatigue life area.

If tests for confirmation of the fatigue limit resistance are performed, test specimens reaching the limit number of cycles without failure shall be tested again at a higher load level (assessment of non-damaged specimens). This run-out test shall be applied to identify a potential damage of the test specimen despite reaching the limit number of cycles.

I.2 Procedural steps

I.2.1 Planning of the fatigue tests

The number of cycles to failure n for each load range ΔV_y or ΔV_x shall be determined by testing. The test results shall be used for the determination of the fatigue resistance function.

The load range ΔV_y or ΔV_x is defined as the difference between upper and lower level for every load level $\Delta V_y = V_{y,up} - V_{y,lo}$ or $\Delta V_x = V_{x,up} - V_{x,lo}$ according to Figure 2.2.1.1.2 for pulsating loading ($V_{y,lo}$ and $V_{x,lo}$ = 0 or certain value) and according to Figure 2.2.1.3.1 for alternating loading ($V_{y,lo} = -V_{y,up}$ and $V_{x,lo} = -V_{x,up}$).

For the determination of the characteristic fatigue resistance with origin load, $\Delta V_{Rk,s,y,0,n}$ or $\Delta V_{Rk,s,x,0,n}$, the lower level of the sinusoidal shape $V_{y,lo}$ or $V_{x,lo}$ is equal for all fatigue cyclic load levels and shall be kept to a minimum in the pulsating range.

For the determination of the characteristic fatigue resistance with an arbitrary lower load, $\Delta V_{Rk,y,s,lo,n}$ or $\Delta V_{Rk,x,s,lo,n}$, fatigue tests shall be carried out in the pulsating range with certain values of lower load or a constant upper load level depend on the intended use of the product (see 1.2.1). The chosen load level shall be kept constant throughout the entire test programme.

For the determination of the unfavourable type of loading under shear load, fatigue tests shall be performed in the alternating range with same upper and lower load level of different algebraic sign, which corresponds to a constant mean load level of zero ($V_{y,m}$=0 and $V_{x,m}$=0).

The specimens shall be subjected to fatigue cyclic load levels in the elastic range. Maximum load levels which lead to failure in the low-cycle fatigue region of $n < 5 \cdot 10^3$ load cycles shall not be included in the confirmation.

Note: As orientation for the elastic range limit of the specimen results from tests under static and quasi-static shear loading shall be used or static reference tests shall be performed.

I.2.2 Determination of the unfavourable loading position for fatigue loading

For the determination of the unfavourable loading position six pulsating tests shall be performed with identical fatigue cyclic load levels for each relevant position (Figure 2.2.1.1.2 under perpendicular shear and Figure 2.2.2.1.1 under longitudinal shear).

The six load levels shall be uniformly distributed along the S/N-curve using nearly equidistant distances between the load levels in the logarithmic scale. At least one specimen shall be tested in the area of $n > 1{\cdot}10^6$ load cycles.

Tests which belong to the unfavourable decisive loading position shall be included in the final confirmation (see clause I.2.5).

I.2.3 Determination of the characteristic static resistance

If fatigue tests are performed with certain values of lower load or a constant upper load level, at least three static tests ($n \geq 3$) shall be performed for the unfavourable loading position under fatigue loading as determined in clause I.2.2.

For the determination of the static, finite life fatigue and fatigue limit resistances testing shall be done on the identical product regarding batch, geometry, material etc.

The characteristic value of the reference static resistance shall be determined in accordance with EAD 330008-04-0601 [1], Annex A, clause A.3.

$$V_{k,y,ref} = F_{5\%} \tag{I.2.3.1}$$

$$V_{k,x,ref} = F_{5\%} \tag{I.2.3.2}$$

where $F_{5\%}$ according to EAD 330008-04-0601 [1], Annex A, Equation (A.3.1)

I.2.4 Determination of the unfavourable type of loading under shear

If the performance of anchor channels under fatigue shear loading is assessed, the unfavourable type of loading shall be obtained for both shear perpendicular (y) to the longitudinal (x) channel axis and shear in the direction of the longitudinal (x) channel axis since the loads may occur in the pulsating range and/or in the alternating range. For the determination of the unfavourable type of loading six alternating shear tests with different load ranges shall be performed in the unfavourable loading position for each load direction.

For the six load levels, the identical load ranges shall be chosen as in the pulsating tests for the determination of the unfavourable loading position (see clause I.2.2). The mean load of zero ($F_m = 0$) is equal for all load levels and shall be kept constant during the tests.

The alternating test results shall be compared with the corresponding results of the pulsating tests obtained in the unfavourable loading position.

Tests which belong to the unfavourable decisive type of loading shall be included in the final confirmation (see clause I.2.5).

I.2.5 Determination of the characteristic fatigue resistance in the finite fatigue life area

For the determination of the characteristic fatigue resistance in the finite fatigue life, at least 16 tests (FC10 and FC17 according to Annex B, Table B.1.1) with different load ranges shall be performed for the unfavourable loading position and type of loading.

The load levels shall be uniformly distributed in the finite fatigue life area of the S/N-curve using nearly equidistant distances between the load levels in the logarithmic scale. The load levels shall be chosen in order to aim fatigue failure between $n = 10^4$ and $n = 10^6$ load cycles for carbon steel and between $n = 10^4$ and $n = 5{\cdot}10^6$ load cycles for stainless steel. For stainless steel at least two tests shall fail at $n \geq 10^6$ load cycles.

Tests with failure at $n \geq 5{\cdot}10^3$ load cycles shall be taken into account for the confirmation. Tests which are stopped without failure shall not be included in the confirmation. Failures at $n > 2{\cdot}10^6$ load cycles shall only be taken into account if the regression line is unfavourable under this assumption, that means the regression line with considering failures at $n > 2{\cdot}10^6$ load cycles is situated below the regression line without considering failures at $n > 2{\cdot}10^6$.

The characteristic fatigue resistance function shall be determined by statistical evaluation based on the 5%-quantile with a confidence level of 90%.

For the confirmation of the test results, the characteristic values shall be calculated by the following procedure:

The mean value curve shall be determined by linear regression analyses of the test data on logarithmic scale using the least squares method. The test data shall be described by a straight line:

$$y_i = a + b \cdot x_i \tag{I.2.5.1}$$

where:

y_i dependent variable of the regression curve for test result i
x_i independent variable of the regression curve for test result i
a, b regression parameter for the regression curve

The best fit for the test results shall be obtained from the condition that the sum of the squares of residuals is becoming a minimum. Depending on the definition of the dependent variable, two different regression lines shall be defined. The first line $y_1 = a_y + b_y \cdot x$ shall be determined for the assumed dependency of the number of load cycles according to Equations (I.2.5.2) and (I.2.5.3) and the second line $y_2 = a_x + b_x \cdot x$ for the assumed dependency of the load range according to Equations (I.2.5.4) and (I.2.5.5). The parameters a_y / a_x and b_y / b_x shall be calculated as follows:

Regression line y_1

$$a_y = \bar{y} - b_y \cdot \bar{x} \quad \text{(I.2.5.2)} \qquad b_y = \frac{m \cdot \sum(x_i\, y_i) - (\sum x_i) \cdot (\sum y_i)}{m \cdot \sum {x_i}^2 - (\sum x_i)^2} \quad \text{(I.2.5.3)}$$

where:

y_i dependent variable as the decimal logarithm of the number of load cycles = lgn_i
x_i independent variable as the decimal logarithm of the load range = $lg\Delta V_{y,i}$ and = $lg\Delta V_{x,i}$
m number of test results
$\bar{y}$ and $\bar{x}$ mean values of y_i and x_i respectively

Regression line y_2

$$a_x = \bar{y} - b_x \cdot \bar{x} \quad \text{(I.2.5.4)} \qquad b_x = \frac{m \cdot \sum(x_i\, y_i) - (\sum x_i) \cdot (\sum y_i)}{m \cdot \sum {x_i}^2 - (\sum x_i)^2} \quad \text{(I.2.5.5)}$$

where:

y_i dependent variable as the decimal logarithm of the load range = $lg\Delta V_{y,i}$ and = $lg\Delta V_{x,i}$
x_i independent variable as the decimal logarithm of the number of load cycles = lgn_i

The resulting regression line shown in Figure I.2.5.1 is given with Equation (I.2.5.6) as the average function of the two obtained lines, which is crossing the centre of the test results with a mean slope b_m according to Equations (I.2.5.7) and (I.2.5.8):

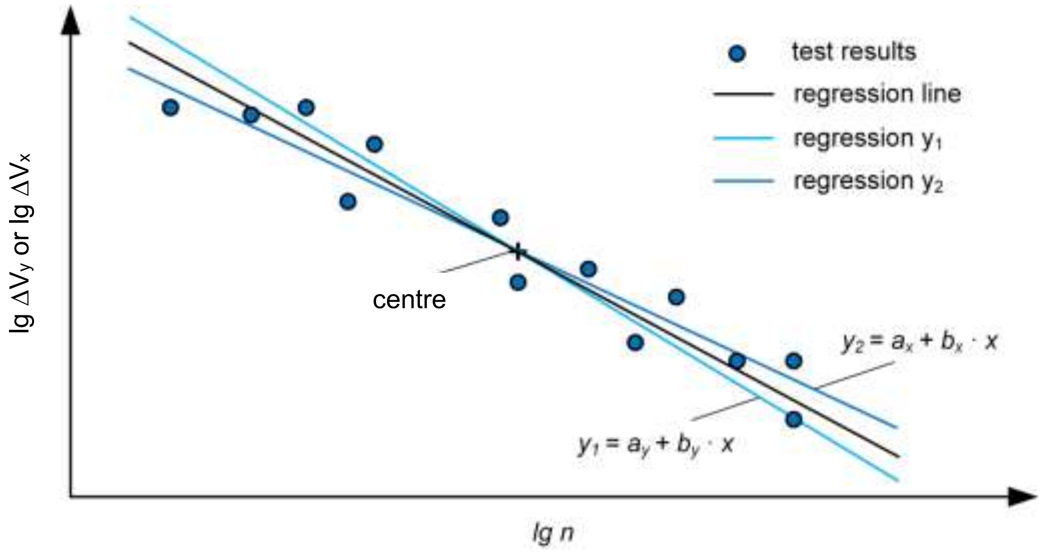
$$y = a_m + b_m \cdot x \tag{I.2.5.6}$$

where:

y decimal logarithm of the number of load cycles = lgn_i
x decimal logarithm of the load range = $lg\Delta V_{y,i}$ and = $lg\Delta V_{x,i}$

$$a_m = \bar{y} - b_m \cdot \bar{x} \tag{I.2.5.7}$$

$$b_m = \left(b_y + {}^1/_{b_x}\right)/2 \tag{I.2.5.8}$$



ΔV_y load range of fatigue cyclic loading perpendicular (y) to longitudinal (x) channel axis

ΔV_x load range of fatigue cyclic loading in the direction of longitudinal (x) channel axis

n number of load cycles

Figure I.2.5.1: Linear regression of test data

The standard deviation shall be estimated as follows:

$$s = \sqrt{\frac{S_{yy} - b_m \cdot S_{xy}}{m-2}} \quad \text{(I.2.5.9)}$$

where:

$$S_{yy} = \sum y_i^2 - \frac{1}{m}\left(\sum y_i\right)^2 \quad \text{(I.2.5.10)}$$

$$S_{xy} = \sum x_i\, y_i - \frac{1}{m}\left(\sum x_i \sum y_i\right) \quad \text{(I.2.5.11)}$$

x_i, y_i see legend of Equation (I.2.5.3)

b_m regression parameter of the mean value curve, see Equation (I.2.5.8)

m number of test results

The lower confidence limit shall be evaluated using the 5%-quantile value of the regression line (see Figure I.2.5.2). The characteristic values of the fatigue resistance curve shall be described by the following Equation:

$$lg\,(n) = a_m + b_m \cdot lg\,(\Delta V_y) - k_s \cdot s \quad \text{(I.2.5.12a)}$$

$$lg\,(n) = a_m + b_m \cdot lg\,(\Delta V_x) - k_s \cdot s \quad \text{(I.2.5.12b)}$$

where:

n number of load cycles

ΔV_y load range of fatigue cyclic loading perpendicular (y) to longitudinal (x) channel axis

ΔV_x load range of fatigue cyclic loading in the direction of longitudinal (x) channel axis

a_m, b_m see Equations (I.2.5.7) and (I.2.5.8)

k_s statistical tolerance factor for a confidence level of 90% and unknown standard deviation, see EAD 330008-04-0601 [1], Annex A, Equation (A.3.1)

s standard deviation, see Equation (I.2.5.9)

The characteristic fatigue resistance $\Delta V_{k,y,n}$ or $\Delta V_{k,x,n}$ for n load cycles shall, thus, be obtained as:

$$\Delta V_{k,y,n} = 10^{\,(a + b \cdot lg(n))} \leq \Delta V_{i,y,max} \quad \text{(I.2.5.13a)}$$

$$\Delta V_{k,x,n} = 10^{\,(a + b \cdot lg(n))} \leq \Delta V_{i,x,max} \quad \text{(I.2.5.13b)}$$

where:

$$a = \left(\frac{k_s \cdot s - a_m}{b_m}\right) \qquad \text{(I.2.5.14)}$$

$$b = \left(\frac{1}{b_m}\right) \qquad \text{(I.2.5.15)}$$

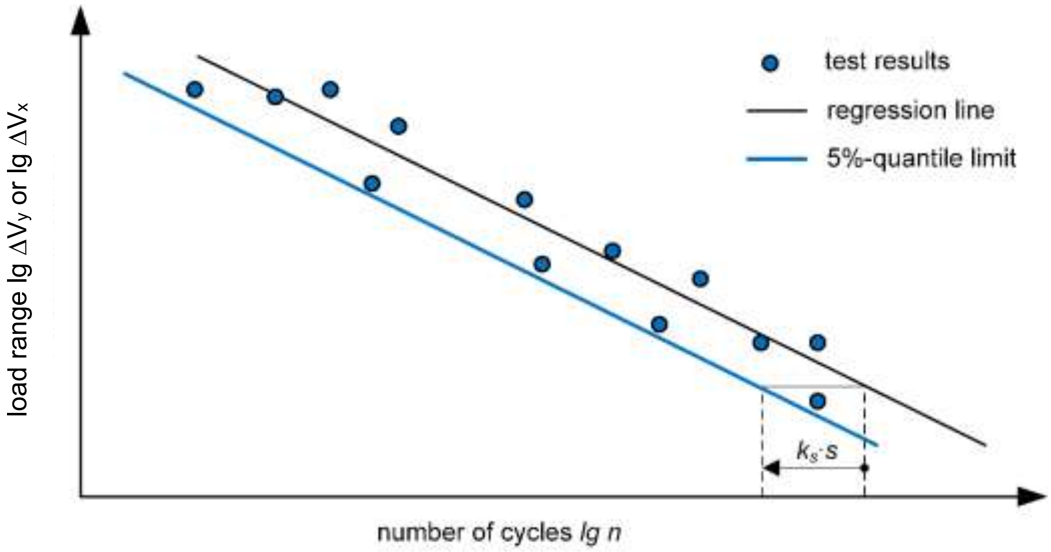
$\Delta V_{i,y,max}$ maximum load range applied for test result i

$\Delta V_{i,x,max}$ maximum load range applied for test result i

n number of load cycles

a_m, b_m see Equations (I.2.5.7) and (I.2.5.8)

k_s, s see Equations (I.2.5.12)



ΔV_y load range of fatigue cyclic loading perpendicular (y) to longitudinal (x) channel axis

ΔV_x load range of fatigue cyclic loading in the direction of longitudinal (x) channel axis

n number of load cycles

Figure I.2.5.2: Statistical evaluation of the lower 5%-quantile limit

I.2.6 Confirmation of the characteristic fatigue limit resistance

The lower bound of the fatigue resistance curve shall be defined as the fatigue limit, in which case the calculated regression line becomes a horizontal line.

If no tests have been performed, the characteristic fatigue limit resistance $\Delta V_{D,k,y}$ or $\Delta V_{D,k,x}$ shall be determined using the characteristic value of the regression line according to Equations (I.2.5.13) for *n* = $1 \cdot 10^8$ load cycles.

For the confirmation of the fatigue limit resistance at least four run-out specimens reaching the limit number of cycles are performed for the unfavourable loading position. The limit number of cycles n_{lim} for these tests is located at $5 \cdot 10^6$ load cycles for carbon steel or $7 \cdot 10^6$ load cycles for stainless steel.

The load level for the run-out tests shall be chosen in a way that the mean value of the four load ranges $\Delta V_{m,lim,y}$ or $\Delta V_{m,lim,x}$is larger than or equal to the mean fatigue resistance $\Delta V_{D,y}$ or $\Delta V_{D,x}$ for n_{lim} load cycles that is taken from the regression line of the test results according to Equation (I.2.5.6).

Test specimen reaching the limit number of cycles without failure shall be tested again with a higher load range until failure occurs. The load level of the second test $\Delta V_{RT,y}$ or $\Delta V_{RT,x}$ shall be arranged in the upper third of the finite fatigue life area. The specimen shall be considered as run-out specimen on the first load level, if the number of cycles obtained on the second load level exceeds the 5%-quantile function according to Equation (I.2.5.12a) and Equation (I.2.5.12b). If the run-out test is not passed, then the specimen was damaged during the first load level and shall not considered as a run-out specimen.

If the pre-test results show a crossing point between testing in Position 1 and Position 2 (see Figure 2.2.1.1.4) and a run-out specimen on first (lowest) load level is obtained in unfavourable position (e.g., Position 1), then the fatigue test on second load level located above the crossing point shall be performed in the same position.

Since the result of second load level belongs to the range obtained for the favourable position, the 5%-quantile limit of the favourable position shall be calculated by assuming the same scatter as for the unfavourable position as shown in EAD 330008-04-0601 [1], Annex C, Figure C.2.4.4. Then the same conditions as described in the preceding paragraph apply for the run-out test assessment.

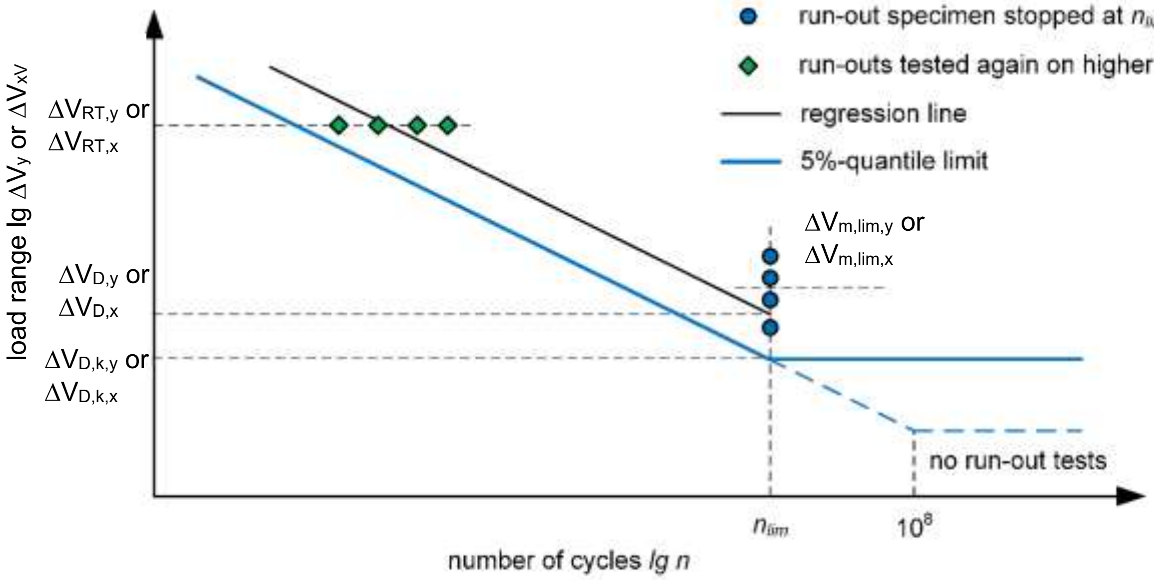
If all four specimens are assessed as run-out, then the characteristic fatigue limit resistance $\Delta V_{D,k,y}$ or $\Delta V_{D,k,x}$ shall be determined using the characteristic value of the regression line according to Equations (I.2.5.13) for n_{lim} load cycles. If not sufficient run-out specimens can be assessed, then the limit number of cycles shall be increased and testing for the confirmation of the fatigue limit resistance shall be started again from the beginning.

Note: The following ranges can serve as an orientation for the expected limit number of cycles n_{lim}:

Carbon steel: $5 \cdot 10^6 \leq n_{lim} \leq 8 \cdot 10^6$

Stainless steel: $7 \cdot 10^6 \leq n_{lim} \leq 1 \cdot 10^7$

An example for the determination of the characteristic fatigue limit resistance is provided in Figure I.2.6.1.



$\Delta V_{RT,y}$	load range for run-out tests under shear load perpendicular (y) to longitudinal (x) channel axis
$\Delta V_{RT,x}$	load range for run-out tests under shear load in the direction of longitudinal (x) channel axis
$\Delta V_{D,y}$	mean load range of fatigue limit resistance under shear load perpendicular (y) to longitudinal (x) channel axis
$\Delta V_{D,x}$	mean load range of fatigue limit resistance under shear load in the direction of longitudinal (x) channel axis
$\Delta V_{D,k,y}$	characteristic fatigue limit resistance under shear load perpendicular (y) to longitudinal (x) channel axis
$\Delta V_{D,k,x}$	characteristic fatigue limit resistance under shear load in the direction of longitudinal (x) channel axis
$\Delta V_{m,lim,y}$	mean value of the four load ranges under shear load perpendicular (y) to longitudinal (x) channel axis
$\Delta V_{m,lim,x}$	mean value of the four load ranges under shear load in the direction of longitudinal (x) channel axis
ΔV_y	load range of fatigue cyclic loading perpendicular (y) to longitudinal (x) channel axis
ΔV_x	load range of fatigue cyclic loading in the direction of longitudinal (x) channel axis
n_{lim}	limit number of load cycles

Figure I.2.6.1: Example for determination of the characteristic fatigue limit resistance

I.2.7 Confirmation of the characteristic fatigue resistance

When the finite life fatigue and the fatigue limit resistances are determined, the resulting characteristic fatigue resistance is provided by a bi-linear function in the double logarithmic scale as shown in Figure I.2.6.1. The fatigue resistance $\Delta V_{Rk,s,y,lo,n}$ or $\Delta V_{Rk,s,x,lo,n}$ taken from the S/N-curve is valid for fatigue loading with the corresponding level of lower load that was applied during the final tests.

For fatigue tests performed in the pulsating range with certain level of lower load ($V_{y,lo}$ > 0), the lower load shall be reduced by the reduction factor $\eta_{k,red}$ taking into account the reference static resistance as follows:

$$\eta_{k,y,red} = \frac{V_{Rk,s,y}}{V_{k,y,ref}} \leq 1{,}0 \qquad \text{(I.2.7.1a)}$$

where:

$V_{Rk,s,y}$ $min\ (V_{Rk,s,a,y}\,, V_{Rk,s,c,y}, V^0_{Rk,s,l,y}, V_{Rk,s}\,)$,

minimum characteristic value of static resistance for steel failure as determined by static shear tests perpendicular (y) to the longitudinal (x) channel axis with

$V_{Rk,s,a,y}\,, V_{Rk,s,c,y}, V^0_{Rk,s,l,y}$ in accordance with EAD 330008-04-0601 [1], clause 2.2.14

$V_{Rk,s}$ in accordance with EAD 330008-04-0601 [1], clause 2.2.12

$V_{k,y,ref}$ see Equation (I.2.3.1), characteristic value of reference static resistance as determined from test series FC8

$$\eta_{k,x,red} = \frac{V_{Rk,s,x}}{V_{k,x,ref}} \leq 1{,}0 \qquad \text{(I.2.7.1b)}$$

where:

$V_{Rk,s,x}$ $min\ (V_{Rk,s,a,x}\,, V_{Rk,s,c,y}, V_{Rk,s})$,
minimum characteristic value of static resistance for steel failure as determined by static shear tests in the direction of the longitudinal (x) channel axis with

$V_{Rk,s,a,x}\,, V_{Rk,s,c,y}$ in accordance with EAD 330008-04-0601 [1], clause 2.2.17

$V_{Rk,s}$ in accordance with EAD 330008-04-0601 [1], clause 2.2.12

$V_{k,x,ref}$ see Equation (I.2.3.2), characteristic value of reference static resistance as determined from test series FC18

If the fatigue testing has been performed in the pulsating range with constant lower load level, the characteristic value of lower load $V_{lok,s,y,n}$ or $V_{lok,s,x,n}$ shall be calculated according to Equations (I.2.7.2):

$$V_{lok,s,y,n} = \eta_{k,y,red} \cdot V_{y,lo} \qquad \text{(I.2.7.2a)}$$

$$V_{lok,s,x,n} = \eta_{k,x,red} \cdot V_{x,lo} \qquad \text{(I.2.7.2b)}$$

where:

$V_{y,lo}$, $V_{x,lo}$ lower limit of fatigue cyclic loads kept constant during the tests according to the intended use

If the fatigue testing has been performed in the pulsating range with constant upper load level, the characteristic value of lower load $V_{lok,s,y,n}$ or $V_{lok,s,x,n}$ shall be calculated as follows:

$$V_{lok,s,y,n} = \eta_{k,y,red} \cdot (V_{up,y} - \Delta V_{m,y,n}) \geq 0 \qquad \text{(I.2.7.3a)}$$

$$V_{lok,s,x,n} = \eta_{k,x,red} \cdot (V_{up,x} - \Delta V_{m,x,n}) \geq 0 \qquad \text{(I.2.7.3b)}$$

where:

$V_{up,y}$, $V_{up,x}$ upper limit of fatigue cyclic loads kept constant during the tests according to the intended use

$\Delta V_{m,y,n}$, $\Delta V_{m,x,n}$ mean value of fatigue resistance for n load cycles taken from regression line in Figure I.2.5.2

For fatigue shear tests in which the final tests have been performed in the alternating range as the unfavourable type of loading, the characteristic value of lower load $V_{lok,s,y,n}$ or $V_{lok,s,x,n}$ shall be given as follows:

$$V_{lok,s,y,n} = V_{lok,s,x,n} = 0 \qquad \text{(I.2.7.4)}$$