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EAD **333530-00-0601**

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European Assessment Document for

Stainless-steel point connectors for sandwich walls

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 (EU) No 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

The stainless-steel point connectors for sandwich walls are designated in the EAD as "stainless-steel point connector(s)". One stainless-steel (as defined in EN 10088-1[1]) point connector comprises stainless-steel wires and stainless-steel sheet (schematical example see Figure 1.1.1). The stainless-steel wires are spot welded to the stainless-steel sheet. To increase the bond resistance, the stainless-steel wires are corrugated and notched along the length embedded in concrete.

Only the products fulfilling the requirements of class A1 of reaction-to-fire performance in accordance with the Commission Decision (EU) 96/603/EC, amended by Commission Decision (EU) 2000/605/EC of 26 September 2000 and by Commission Decision (EU) 2003/424/EC of 6 June 2003, are considered as included in the scope of this EAD and those products not fulfilling the conditions are outside the scope of the EAD.

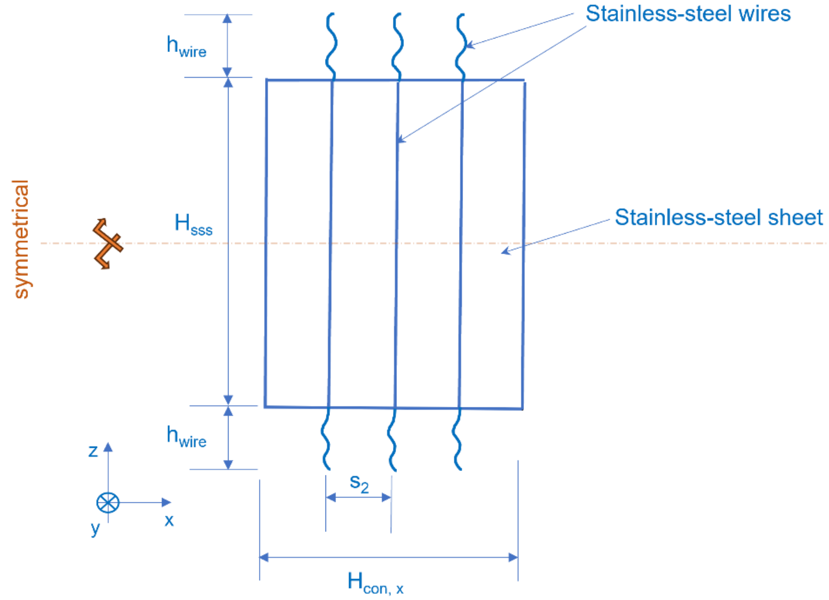


Figure 1.1.1: Stainless-steel point connector for sandwich walls – schematical example with 3 stainless-steel wires showing symmetry in z-direction

Where

h_{wire} .... mm ....Protruding length of stainless-steel wires
H_{sss} .... mm............Full length of stainless-steel sheet
$H_{con,x}$ .... mm............Height of the stainless-steel point connector in x-direction
s_2 .... mm............Centre spacing between the single stainless-steel wires in x-direction

Both ends of the stainless-steel point connectors are intended to be embedded in the concrete of base panel and facing panel of the sandwich wall.

The stainless-steel point connectors are used to connect the two concrete layers and to establish the thickness of the finished wall. The length of the stainless-steel point connector is depending on the thickness of the finished wall.

The stainless-steel point connector is redundant within the sandwich wall. According to the intended use, see Clause 1.2.1, the structure of sandwich wall with the stainless-steel point connectors is designated as a redundant structure. Redundancy with regard to the sandwich wall with the stainless-steel point connectors is the ability of the structure to find load paths even in the event of structural failure of one or more stainless-steel point connectors. Thereby, the consequences of such a structural failure can be contained. Structural failures of stainless-steel point connectors are e. g., excessive deformation due to loss of bond between concrete layer or base/facing panel and stainless-steel point connectors, fracture of the stainless-steel point connectors, et cetera.

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

The product is not covered by a harmonised European standard (hEN) and not covered by a European Assessment Document (EAD).

Concerning product packaging, transport, storage, maintenance, replacement and repair it is the responsibility of the manufacturer to undertake the appropriate measures and to advise his clients on the transport, storage, maintenance, replacement, and repair of the product as he considers necessary.

It is assumed that the product will be installed according to the manufacturer's instructions or (in absence of such instructions) according to the usual practice of the building professionals.

Relevant manufacturer's stipulations, e.g., with regard to the intended end use conditions, having influence on the performance of the product covered by this European Assessment Document shall be considered for the determination of the performance and detailed in the ETA as long as the details of the assessment methods as laid down in this EAD are respected.

1.2 Information on the intended use(s) of the construction product

1.2.1 Intended use(s)

The stainless-steel point connectors are used to connect the base panel and facing panel with a thermal insulation layer and, possibly, a gap between thermal insulation layer and base panel in between, see Figure 1.2.1.1 and Figure 1.2.1.2. The gap between the base panel and the thermal insulation layer can be filled later with concrete.

The sandwich wall shall be subjected to predominantly static and quasi-static actions only.

The stainless-steel point connector is intended to transfer the actions on the facing panel into the base panel. The facing panel can be installed unsupported or supported, see Figure 1.2.1.3.

The facing panel is always non-loadbearing whereas the base panel can be either loadbearing or non-load bearing. However, the facing panel and the base panel of the sandwich wall are not part of this EAD.

The stainless-steel point connectors are intended to be used in uncracked concrete of strength classes from C25/30 to C50/60 according to EN 206, clause 4.3.1.

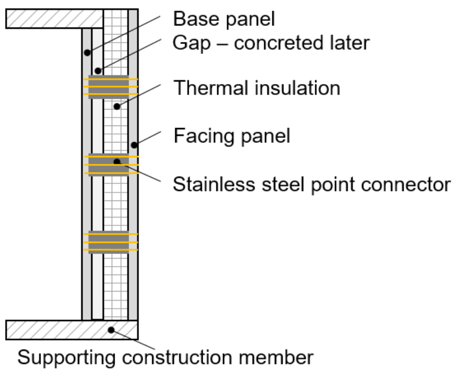


Figure 1.2.1.1: Cross section of a sandwich wall, assembled with stainless-steel point connectors; with gap between thermal insulation layer and base panel

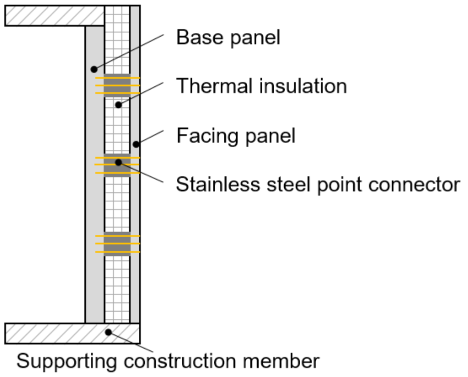


Figure 1.2.1.2: Cross section of a sandwich wall, assembled with stainless-steel point connectors; without gap between thermal insulation layer and base panel

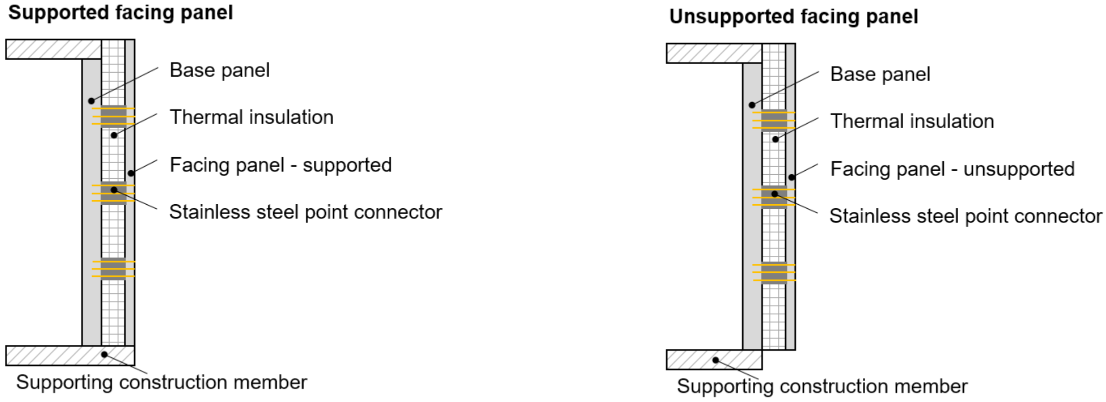


Figure 1.2.1.3: Supported and non-supported sandwich wall, assembled with stainless-steel point connectors; without gap between thermal insulation layer and base panel

1.2.2 Working life/Durability

The assessment methods included or referred to in this EAD have been written based on the manufacturer's request to take into account a working life of the stainless-steel point connectors for the intended use of 50 years when installed in the works (provided that the stainless-steel point connectors are subject to appropriate installation (see 1.1). These provisions are based upon the current state of the art and the available knowledge and experience.

When assessing the product, the intended use as foreseen by the manufacturer shall be taken into account. The real working life may be, in normal use conditions, considerably longer without major degradation affecting the basic requirements for works[2].

The indications given as to the working life of the construction product cannot be interpreted as a guarantee neither given by the product manufacturer or his representative nor by EOTA when drafting this EAD nor by the Technical Assessment Body issuing an ETA based on this EAD, but are regarded only as a means for expressing the expected economically reasonable working life of the product.

[2] The real working life of a product incorporated in a specific works depends on the environmental conditions to which that works is subject, as well as on the particular conditions of the design, execution, use and maintenance of that works. Therefore, it cannot be excluded that in certain cases the real working life of the product may also be shorter than the working life referred to above.

1.3 Specific terms used in this EAD

1.3.1 MPII

MPII are the Manufacturer’s Product Installation Instructions.

1.3.2 Symbols

Note: Eurocode, EN 1992-4, is explored as the source of standardised definitions, symbols and units.

1.3.2.1 Indices

t .... –.............tension, pull-out
0 .... –.............start of the testing
i .... –.............test “i”
ucr .... –.............in uncracked concrete
u .... –.............ultimate
n .... –.............number of tests
R .... –.............resistance
Rk, t, ucr .... –.............characteristic value of resistance, in tension, in uncracked concrete
R5%, v................................... –.............5%-fractile, shear
cy, t...................................... –.............tension after cyclic tensile loading
cy, vt .... –.............tension after cyclic shear loading
cv, t...................................... –.............tension, considering coefficient of variation
cv, cy, t .... –.............tension after cycling tensile loading, considering coefficient of variation
cv, cy, vt................................ –.............tension after cycling shear loading, considering coefficient of variation
cy, vv.................................... –.............shear after cyclic shear loading
cv, v .... –.............shear, considering coefficient of variation
cv, cy, vv .... –.............shear after cyclic shear loading, considering coefficient of variation
c.. –.............cube
ec .... –.............eccentricity
nom .... –.............nominal
ef... –.............effective
st... –.............steel
wire...................................... –.............stainless-steel wire
sss....................................... –.............stainless-steel sheet
1 .... –.............in direction 1
2 .... –.............in direction 2
x.. –.............in direction x
y.. –.............in direction y
min .... –.............minimum
max...................................... –.............maximum
min, x .... –.............minimum in x-direction
min, y .... –.............minimum in y-direction
sp .... –.............splitting
cp .... –.............concrete pry-out
con, x .... –.............connector, in x-direction

1.3.2.2 Upper case and lower-case letters

Clause 1.1:
h_{wire}.................................. mm ....Protruding length of stainless-steel wires
H_{sss}.................................. mm...........Full length of stainless-steel sheet
$H_{con, x}$ .... mm...........Height of the stainless-steel point connector in x-direction
s_2...................................... mm...........Centre spacing between the single stainless-steel wires in x-direction

Clause 2.2.3:

$t_{fp, min, 0}$ .... mm ....Minimum thickness of facing panel at the start of the testing

h_{wire} ...... mm ...... Protruding length of stainless-steel wires
h_t ...... mm ...... Embedment depth of single stainless-steel wire, in concrete considering tolerances
z_0 ...... mm ...... Thickness of unreinforced concrete plate at the start of the testing
z ...... mm ...... Thickness of unreinforced concrete plate
z_{lts} ...... mm ...... Thickness of unreinforced concrete plate in the last testing series with steel failure
$N_{Ru, t, ucr, C25/30, i}$ ...... N ...... Ultimate tensile force converted to uncracked C25/30 for each test i
f_c ...... MPa ...... Concrete compressive strength of 30 MPa, cube
$f_{c, test}$ ...... MPa ...... Concrete compressive strength at the day of testing, cube
$N_{Ru, t, ucr, i}$ ...... N ...... Ultimate tensile force in pull-out test i
$N_{Rk, t, ucr}$ ...... N ...... Resistance to steel failure and combined pull-out and concrete cone failure of the single stainless-steel wire (in uncracked concrete)
$\alpha_{cy, t}$ ...... — ...... Reduction factor for pull-out after cyclic tensile loading
$\alpha_{cy, vt}$ ...... — ...... Reduction factor for pull-out after cyclic shear loading
$\beta_{cv, t}$ ...... — ...... Reduction factor for large scatter of ultimate pull-out forces
$\beta_{cv, cy, t}$ ...... — ...... Reduction factor for large scatter of ultimate pull-out forces after cyclic tensile loading
$\beta_{cv, cy, vt}$ ...... — ...... Reduction factor for large scatter of ultimate pull-out forces after cyclic shear loading
cv_t ...... % ...... Coefficient of variation of ultimate pull-out forces
R_m ...... MPa ...... Tensile strength of stainless-steel wires, EN 10088-3
$R_{m, test}$ ...... MPa ...... Tensile strength of stainless-steel wires used in pull-out test, inspection certificate 3.1
$N_{Ru, t, ucr, st, i}$ ...... N ...... Converted ultimate tensile force in pull-out test i, in the case of steel failure
$N_{R5\%, t, ucr}$ ...... N ...... 5 %-fractile at a confidence level of 90 %[3] of ultimate forces for steel failure and combined pull-out and concrete cone failure in uncracked concrete
$t_{fp, min}$ ...... mm ...... Minimum thickness of facing panel

Clause 2.2.4:

z ...... mm ...... Thickness of unreinforced concrete plate
$t_{fp, min}$ ...... mm ...... Minimum thickness of facing panel
$N_{Rm, t, cy, t}$ ...... N ...... Mean ultimate pull-out force of the cycling tensile loading test series
$N_{Rm, t, ucr}$ ...... N ...... Mean ultimate pull-out force of results according to Clause 2.2.3
$N_{R5\%, t, cy, t}$ ...... N ...... 5 %-fractile of ultimate pull-out forces of the cycling tensile loading test series
$N_{R5\%, t, ucr}$ ...... N ...... 5 %-fractile of ultimate forces of results according to Clause 2.2.3
$\alpha_{cy, t}$ ...... — ...... Reduction factor for pull-out after cyclic tensile loading
$\beta_{cv, cy, t}$ ...... — ...... Reduction factor for large scatter of pull-out after cyclic tensile loading
$cv_{cy, t}$ ...... % ...... Coefficient of variation of ultimate tension forces after cycling tensile loading
N_{cyc} ...... — ...... Number of cycles

Clause 2.2.5:

h_{ef} ...... mm ...... Effective embedment depth of single stainless-steel wire in concrete
f_{ck} ...... N/mm^2 ...... Concrete compressive strength, C25/30
$N_{R5\%, t, ucr}$ ...... N ...... 5 %-fractile of ultimate forces of results according to Clause 2.2.3
k_1 ...... (N/mm)^{0,5} ...... Factor k_1 = 12,7 (N/mm)^{0,5}
$N_{Rk, c}$ ...... N ...... Characteristic value of resistance of a stainless-steel point connector to concrete cone failure (due to tension loading) as a group of stainless-steel wires
$N_{Rk, t, ucr}$ ...... N ...... Resistance to steel failure and combined pull-out and concrete cone failure of the single stainless-steel wires$_2$ mm Centre spacing between the single stainless-steel wires in x-direction
$A^0_{c, N}$ ...... mm^2 ...... Reference area
$A_{c, N}$ ...... mm^2 ...... Actual area, limited by overlapping concrete cones of adjacent stainless-steel wires ($s \leq s_{cr, N}$) as well as by edges of the concrete member ($c \leq c_{cr, N}$)

[3] For calculation of 5 %-fractile see Annex A.

$s_{cr, N}$ ... mm ... Side length of the square of the reference area
s_{SSPc} ... mm ... Centre spacing between the outmost stainless-steel wires of a stainless-steel point connector as a group of stainless-steel wires

Clause 2.2.6:

c_1 ... mm ... Edge distance in direction „1"
c_2 ... mm ... Edge distance in direction „2"
$c_{ucr, sp}$ ... mm ... Edge distance without splitting
h_t ... mm ... Embedment depth of single stainless-steel wire, in concrete considering tolerances
$s_{ucr, sp}$ ... mm ... Spacing

Clause 2.2.7:

$V_{Rk, cp}$ ... N ... Characteristic value of resistance to concrete pry-out failure (due to shear loading) of a stainless-steel point connector (as a group of stainless-steel wires)
$N_{Rk, c}$ ... N ... Characteristic value of resistance of a stainless-steel point connector (as a group of stainless-steel wires) to concrete cone failure (due to tension loading)
k_8 ... — ... Factor

Clause 2.2.8:

$V_{Rk, c}$ ... N ... Characteristic value of resistance of a stainless-steel point connector (as a group of stainless-steel wires) to concrete edge failure (due to shear loading)
$V^0_{Rk, c}$ ... N ... Initial value of the characteristic resistance of one stainless-steel wire that is loaded perpendicular to the edge
$A^0_{c, V}$ ... mm^2 ... Reference projected area for one stainless-steel wire
$A_{c, V}$ ... mm^2 ... Area of the idealized concrete break out body, limited by the overlapping concrete cones of adjacent stainless-steel wires and by member thickness ($z_1 < 1{,}5 \cdot c_1$)
d_{nom} ... mm ... Diameter of stainless-steel wire
c_1 ... mm ... Edge distance in direction "1"
h_{ef} ... mm ... Effective embedment depth of single stainless-steel wire in concrete
f_{ck} ... N/mm^2 ... Concrete compressive strength, C25/30
$\psi_{h, V}$ ... — ... Factor
z_1 ... mm ... Thickness of unreinforced concrete plate, without tolerances
α, β ... — ... Exponent
$t_{fp, min}$ ... mm ... Minimum thickness of facing panel

Clause 2.2.9 and Clause 2.2.10:

$c_{ucr, sp}$ ... mm ... Minimum edge distance from the assessment of concrete splitting failure
c_{po} ... mm ... Minimum edge distance from the assessment of concrete pry-out failure
c_1 ... mm ... Edge distance in direction "1"
h_{ef} ... mm ... Effective embedment depth of single stainless-steel wire in concrete
c_{ef} ... mm ... Minimum edge distance from the assessment of concrete edge failure
$s_{min, sp}$ ... mm ... Minimum centre spacing from the assessment of concrete splitting failure
$s_{min, po}$ ... mm ... Minimum centre spacing from the assessment of concrete pry-out failure
$s_{min, ef}$ ... mm ... Minimum centre spacing from the assessment of concrete edge failure
s_{min} ... mm ... Minimum centre spacing between the stainless-steel point connectors of the respective failure mode

Clause 2.2.11:

F ... N ... Force
d_{max} ... mm ... Maximum clearance between base panel and facing panel
h ... mm ... Embedment depth of stainless-steel point connector, $h = h_{wire} + h_{sss}$
h_{min} ... mm ... Minimum embedment depth of stainless-steel point connector
h_{wire} ... mm ... Protruding length of stainless-steel wires
h_{sss} ... mm ... Embedment depth of stainless-steel sheet in the concrete

H_{sss} .... mm............Total length of stainless-steel sheet
$t_{fp, min}$ .... mm ....Minimum thickness of facing panel
$t_{bp, min}$ .... mm............Minimum thickness of base panel
$c_{min, x}$ .... mm............Minimum edge distance in x-direction of the stainless-steel point connector
$c_{min, y}$ .... mm............Minimum edge distance in y-direction of the stainless-steel point connector
$s_{min, y}$ .... mm............Minimum centre spacing in y-direction of the stainless-steel point connector
$H_{con, x}$ .... mm............Height of the stainless-steel point connector in x-direction
H .... mm............Height of the base or facing panel
B.. mm............Width of the base or facing panel
$c_{ucr, sp}$ .... mm............Minimum edge distance from the assessment of concrete splitting failure
c_{po}..................................... mm............Minimum edge distance for concrete pry-out failure
c_{ef} .... mm............Minimum edge distance from the assessment of concrete edge failure
$V_{Rk, v}$ ....N ....Characteristic value of the resistance to shear
$V_{R5 \%, v}$ ....N ....5 %-fractile of ultimate shear forces
$\alpha_{cy, vv}$ .... —.............Reduction factor for shear after cyclic shear loading
$\beta_{cv, v}$ .... —.............Reduction factor for large scatter of ultimate shear forces
$\beta_{cv, cy, vv}$ .... —.............Reduction factor for large scatter of ultimate shear forces after cyclic shear loading
cv_{v} ....% ....Coefficient of variation of ultimate shear forces

Clause 2.2.12:

$V_{Rk, v}$ ....N ....Characteristic value of the resistance to shear
ΔF..N ....Force variation
ΔS .... mm............Displacement variation corresponding to ΔF
k .... N/mm ....Displacement module
d_{max}.................................... mm............Maximum clearance between base panel and facing panel
$t_{fp, min}$ .... mm............Minimum thickness of facing panel
$t_{bp, min}$ .... mm............Minimum thickness of base panel
$k_{min, x}$.................................. N/mm ....5 %-fractile values for the minimum displacement module at a confidence level of 75 % of the stiffness in shear in x-direction
$k_{max, x}$.................................. N/mm ....95 %-fractile values for the maximum displacement module at a confidence level of 75 % of the stiffness in shear in x-direction
$k_{max, y}$.................................. N/mm ....95 %-fractile values for the maximum displacement module at a confidence level of 75 % of the stiffness in shear in y-direction

Clause 2.2.13:

B.. mm............Width of base panel or facing panel, as width of the stainless-steel point connector + 100 mm
$t_{fp, m}$ .... mm............Mean thickness of facing panel
$t_{bp, min}$ .... mm............Minimum thickness of base panel
F_{co} ....N ....Compression force
R_{co} ....N ....5 %-fractile values for the resistance to compression load at a confidence level of 90 %

Clause 2.2.14:

d_{min} .... mm............Minimum clearance between base and facing panel
H .... mm............Height of the base or facing panel
B.. mm............Width of the base or facing panel
$t_{fp,m}$ .... mm............Mean thickness of facing panel
$t_{bp,min}$ .... mm............Minimum thickness of base panel
α_{c}..K^{-1}............Linear coefficient of thermal expansion, i.e., $\alpha_c = 10 \cdot 10^{-6}\ K^{-1}$ linear coefficient of thermal expansion for concrete
ΔT..K.............Total temperature difference in K
c .... mm............Maximum height of the horizontal sandwich panel or maximal width of the vertical sandwich panel
v_{h} .... mm............Lateral displacement in mm
$N_{Rm, t, cy, vt}$ ....N ....Mean ultimate pull-out force of the cycling shear test series

$N_{Rm, t, ucr}$ .... N .... Mean ultimate pull-out force of results according to Clause 2.2.3
$N_{R5\,\%, t, cy, vt}$ .... N .... 5 %-fractile of ultimate pull-out forces of the cycling shear test series
$N_{R5\,\%, t, ucr}$ .... N .... 5 %-fractile of ultimate forces of results according to Clause 2.2.3
$V_{Rm, v, cy, vv}$ .... N .... Mean ultimate shear force of the cycling shear test series
$V_{Rm, v}$ .... N .... Mean ultimate shear force of results according to Clause 2.2.11
$V_{R5\,\%, v, cy, vv}$ .... N .... 5 %-fractile of ultimate shear forces of the cycling shear test series
$V_{R5\,\%, v}$ .... N .... 5 %-fractile of ultimate shear forces of results according to Clause 2.2.11
$\alpha_{cy, vt}$ .... — .... Reduction factor for pull-out after cycling shear loading
$\alpha_{cy, vv}$ .... — .... Reduction factor for shear after cycling shear loading
$\beta_{cv, cy, vt}$ .... — .... Reduction factor for large scatter of pull-out forces
$\beta_{cv, cy, vv}$ .... — .... Reduction factor for large scatter of shear forces
$cv_{cy, vt}$ .... % .... Coefficient of variation of ultimate pull-out forces of the cycling shear test series
$cv_{cy, vv}$ .... % .... Coefficient of variation of ultimate shear forces of the cycling shear test series

Annex A:

X_m .... N or N/mm ...... Mean value of ultimate forces or displacement moduli

x_i .... N or N/mm ...... Ultimate force or displacement modulus in test i
k_n .... — .... Factor for calculation of fractiles for n tests
n .... — .... Number of tests
cv .... % .... Coefficient of variation of ultimate forces or displacement moduli

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 stainless-steel point connectors 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

№	Essential characteristic	Assessment method	Type of expression of product performance
Basic requirement for construction works 2: Safety in case of fire			
1	Reaction to fire	2.2.1	class
Basic requirement for construction works 4: Safety and accessibility in use			
2	Coefficient of thermal expansion	2.2.2	level, α_T [$10^{-6} \cdot K^{-1}$]
3	Resistance to steel failure and combined pull-out and concrete cone failure of the single stainless-steel wire (in uncracked concrete)	2.2.3	level, $N_{Rk, t, ucr}$ [N] and $t_{fp, min}$ [mm]
4	Resistance to pull-out failure after tensile cycling loading of the single stainless-steel wire	2.2.4	level, $N_{R5\ \%, t, cy, t}$ [N], N_{cyc} [-]
5	Resistance of a stainless-steel connector to concrete cone failure (due to tension loading) and effective embedment depth	2.2.5	level, $N_{Rk, c}$ [N], h_{ef} [mm]
6	Resistance to concrete splitting failure (due to tension loading) of the single stainless-steel wire	2.2.6	level, $c_{ucr, sp}$ [mm], $s_{ucr, sp}$ [mm]
7	Resistance to concrete pry-out failure (due to shear loading)	2.2.7	level, $V_{Rk, cp}$ [N]
8	Resistance to concrete edge failure (due to shear loading)	2.2.8	level, $V_{Rk, c}$ [N]
9	Minimum edge distance	2.2.9	level, $c_{ucr,sp}$ [mm], c_{po} [mm], c_{ef} [mm]
10	Minimum centre spacing	2.2.10	level, $s_{min, sp}$ [mm], $s_{min, po}$ [mm], $s_{min, ef}$ [mm]
11	Resistance to shear	2.2.11	level, $V_{Rk, v}$ [N]
12	Stiffness in shear (displacement module)	2.2.12	level, $k_{min, x}$ [N/mm], $k_{max, x}$ [N/mm], $k_{max, y}$ [N/mm]
13	Resistance to compression load (buckling and/or punching)	2.2.13	level R_{co} [N] and description
14	Thermal actions – cycling shear loading	2.2.14	level c [mm], $\alpha_{cy, vt}$ [–], $\alpha_{cy, vv}$ [–], $\beta_{cv, cy, vt}$ [–], $\beta_{cv, cy, vv}$ [–] and description

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.

If for any components covered by harmonised standards of European Technical Assessments the manufacturer of the component has included the performance regarding the relevant essential characteristic in the Declaration of Performance, retesting of that component for issuing the ETA under the current EAD is not required.

2.2.1 Reaction to fire

The stainless-steel point connector is considered to satisfy the requirements of class A1 of the reaction-to-fire performance in accordance with the Commission Decision (EU) 96/603/EC, amended by Commission Decision (EU) 2000/605/EC of 26 September 2000 and by Commission Decision (EU) 2003/424/EC of 6 June 2003, without the need for testing on the basis of it fulfilling the conditions set out in that Decision and its intended use being covered by that Decision.

When the conditions referred to above are fulfilled, the performance of stainless-steel point connectors, as defined in the Clause 1.1, is class A1 which shall be stated in the ETA.

2.2.2 Coefficient of thermal expansion

Purpose of the assessment

Subject of assessment is coefficient of thermal expansion of the materials of the stainless-steel sheets and the stainless-steel wires that are representative of this essential characteristic of the stainless-steel point connectors.

Assessment method

The coefficient of thermal expansion α_T of the product shall be taken as the mean value of the tabulated values of coefficient of thermal expansion at 20 °C and 100 °C for each of the used stainless-steel materials from the Annex E of EN 10088-1.

Expression of results

Tabulated value α_T in $[10^{-6} \cdot K^{-1}]$ together with the information on temperature span 20 °C and 100 °C shall be given in the ETA.

2.2.3 Resistance to steel failure and combined pull-out and concrete cone failure of the single stainless-steel wire (in uncracked concrete)

Purpose of the assessment

Subject of assessment is resistance to steel failure and combined pull-out and concrete cone failure of the single stainless-steel wire (in uncracked concrete). In addition, purpose is to find the embedment depth where combined pull-out and concrete cone failure mode changes into steel failure mode. This Clause is also linked with the Clauses 2.2.4 and 2.2.14. These clauses provide with assessment of reduction factors which are necessary to complete the assessment in accordance with this clause. Testing in accordance with Clauses 2.2.4 and 2.2.14 shall be carried out before the calculation according to this clause can be performed.

Assessment method

Characteristic value of the resistance to steel failure and combined pull-out and concrete cone failure of the single stainless-steel wire (in uncracked concrete) $N_{Rk, t, ucr}$ shall be assessed by testing as described further in this clause.

The occurrence of steel failure or combined pull-out and concrete cone failure depends on the embedment depth of the steel wires and concrete strength. The embedment depth shall be equal to the thickness of the concrete layer and concrete strength shall be C25/30. In starting the assessment, minimum concrete thickness of the facing panel $t_{fp, min, 0}$ shall be taken in accordance with Table 2.2.3.1.

Table 2.2.3.1: Values of $t_{fp, min, 0}$

In MPII	Not in MPII
$t_{fp, min, 0}$	$t_{fp, min, 0}$ = 15 mm + h_{wire}

Where

$t_{fp, min, 0}$ .... mm ....Minimum thickness of facing panel at the start of the testing
h_{wire}.................................... mm ....Protruding length of stainless-steel wires, Figure 1.1.1
z_0....................................... mm............Thickness of unreinforced concrete plate at the start of the testing

Testing shall be carried out on a single stainless-steel wire embedded in an unreinforced concrete plate with a thickness of z_0, see Equation (2.2.3.1).

$$z_0 = t_{fp, min, 0} - \text{tolerance}^{1)} \tag{2.2.3.1}$$

1) Tolerance in accordance with EN 13369, Table C.1, column “Cross section dimension” underneath the column “Tightened tolerances”, in accordance with the thickness of unreinforced concrete plate

Concrete plates and concrete specimens (cylinders or cubes for strength testing) shall be cured and stored indoors for seven days. 3 cylinders (diameter/height = 15 cm/ 30 cm) or 3 cubes (side length 15 cm) shall be cured for each concrete plate. Thereafter they may be stored outside, provided they are protected such that frost, rain, and direct sun does not cause a deterioration of the concrete compression and tension strength. The compressive strength of the concrete plate shall be determined in accordance with EN 12390-1, EN 12390-2, and EN 12390-3, on 3 cubes or on 3 cylinders at the time of testing. Tensile strength of stainless-steel wires shall be tested in accordance with EN ISO 6892-1.

A single stainless-steel wire, see Figure 1.1.1, shall be embedded in a concrete plate, with an embedment depth as written above. Embedment in concrete shall be by placing the single stainless-steel wire in fresh concrete and compacting the fresh concrete with the placed single stainless-steel wire. A distance ≥ 2 · h_t between stainless-steel wire and loading device, see Figure 2.2.3.1, shall be observed. The stainless-steel wire shall be connected to the test rig with an adapter and loaded to failure (pull – out test). The force shall be increased in such way that the peak force (ultimate force) occurs after 1 to 3 minutes from commencement. The displacements of the stainless-steel wire relative to the concrete surface shall be measured by either one displacement transducer on the head of the stainless-steel wire or by at least two displacement transducers on either side at a distance of ≥ 1,5 · h_t from the stainless-steel wire, see Figure 2.2.3.1. The mean value of the transducer readings shall be recorded in the latter case.

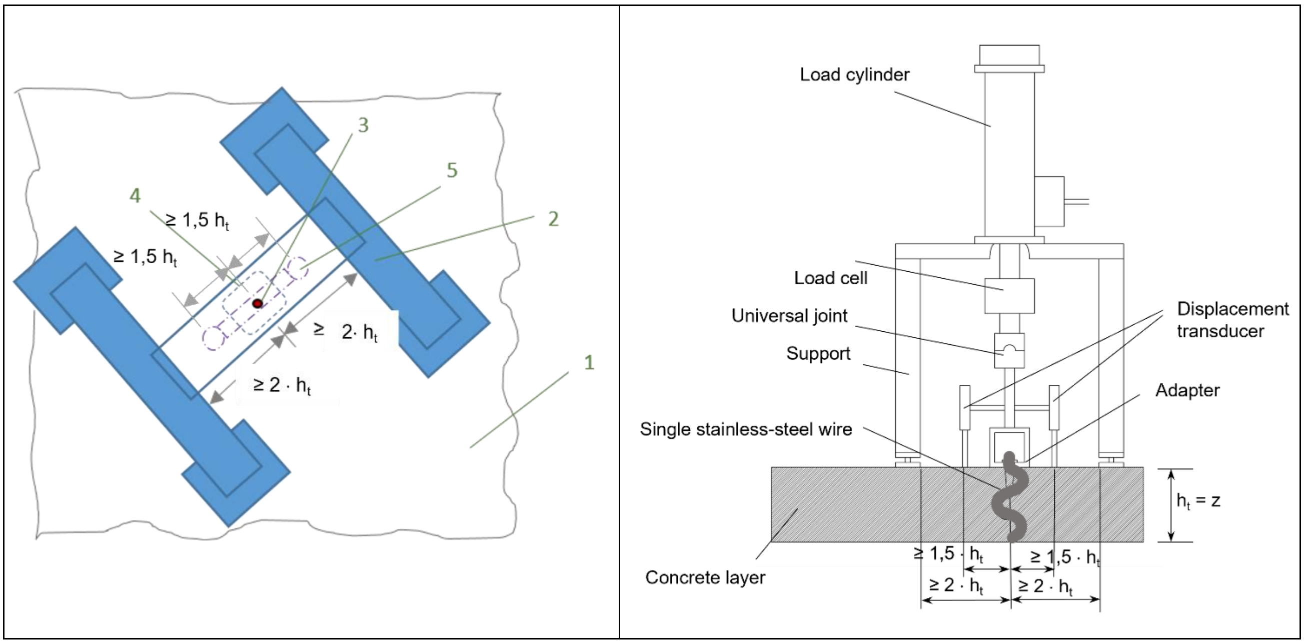


Figure 2.2.3.1: Example of the test rig for tension tests on single stainless-steel wire

Where

1 .... – ....Unreinforced concrete plate, thickness z
2 .... – ....Support of test rig
3 .... – ....Single stainless-steel wire of the stainless-steel point connector
4 .... – ....Loading cylinder with load cell
5 .... – ....Displacement transducer
h_t .... mm...........Embedment depth of single stainless-steel wire in concrete, considering tolerances
z_{lts} .... mm...........Thickness of unreinforced concrete plate in the last testing series with steel failure
z .... mm...........Thickness of unreinforced concrete plate, in actual testing series

5 pull-out failure tests for one thickness of concrete plate shall be summarized in one test series.

With the results of the first test series, continue as given below:

- For only combined pull-out and concrete cone failure within a test series, increase thickness z_{lts} of concrete plate by 5 mm and repeat the test series,
- If steel failure within a test series occurs, terminate testing.

In case of steel failure, the test result shall be converted as shown in Equation (2.2.3.2), prior to calculation of the 5 %-fractile.

$$N_{Ru,\,t,\,ucr,\,st,\,i} = \frac{R_m}{R_{m,\,test}} \cdot N_{Ru,\,t,\,ucr,\,i} \qquad (2.2.3.2)$$

In case of combined pull-out and concrete cone failure, the test result shall be converted to a concrete compressive strength of 30 MPa (cube compressive strength), as shown in Equation (2.2.3.3), prior to calculation of the 5 %-fractile.

$$N_{Ru,\,t,\,ucr,\,C25/30,\,i} = \sqrt{\frac{f_c}{f_{c,\,test}}} \cdot N_{Ru,\,t,\,ucr,\,i} \qquad (2.2.3.3)$$

Calculation of the 5 %-fractile[4] shall be made as shown in Equation (2.2.3.4).

$$N_{R5\%,\,t,\,ucr} = 5\%\ \text{fractile of}\ \left[N_{Ru,\,t,\,ucr,\,C25/30,\,i} \cup N_{Ru,\,t,\,ucr,\,st,\,i} \right] \quad (2.2.3.4)$$

For $cv_t \leq 15$ % see Equation (2.2.3.5):

$$\beta_{cv,\,t} = 1 \quad (2.2.3.5)$$

For $cv_t > 15$ % see Equation (2.2.3.6):

$$\beta_{cv,\,t} = \frac{1}{1 + 0{,}03 \cdot (cv_t - 15)} \quad (2.2.3.6)$$

Resistance to steel failure and combined pull-out and concrete cone failure of the single stainless-steel wire (in uncracked concrete) shall be calculated by Equation (2.2.3.7):

$$N_{Rk,\,t,\,ucr} = N_{R5\,\%,\,t,\,ucr} \cdot \min\left\{\frac{\alpha_{cy,\,t}}{0{,}9} ; \frac{\alpha_{cy,\,vt}}{0{,}8} ; 1{,}0\right\} \cdot \min\left\{\beta_{cv,\,t} ; \beta_{cv,\,cy,\,t} ; \beta_{cv,\,cy,\,vt} ; 1{,}0\right\} \quad (2.2.3.7)$$

Where

$N_{Ru,\,t,\,ucr,\,C25/30,\,I}$	N	Ultimate tensile force converted to uncracked C25/30 for each test i
f_c	MPa	Concrete compressive strength of 30 MPa, cube
$f_{c,\,test}$	MPa	Concrete compressive strength at the day of testing, cube
$N_{Ru,\,t,\,ucr,\,i}$	N	Ultimate tensile force in pull-out test i
$N_{Rk,\,t,\,ucr}$	N	Resistance to steel failure and combined pull-out and concrete cone failure of the single stainless-steel wire (in uncracked concrete)
$\alpha_{cy,\,t}$	—	Reduction factor for pull-out after cyclic tensile loading, see Clause 2.2.4
$\alpha_{cy,\,vt}$	—	Reduction factor for pull-out after cyclic shear loading, see Clause 2.2.14
$\beta_{cv,\,t}$	—	Reduction factor for large scatter of ultimate pull-out forces
$\beta_{cv,\,cy,\,t}$	—	Reduction factor for large scatter of ultimate pull-out forces after cyclic tensile loading, see Clause 2.2.4
$\beta_{cv,\,cy,\,vt}$	—	Reduction factor for large scatter of ultimate pull-out forces after cyclic shear loading, see Clause 2.2.14
cv_t	%	Coefficient of variation of ultimate pull-out forces
R_m	MPa	Tensile strength of stainless-steel wires, EN 10088-3
$R_{m,\,test}$	MPa	Tensile strength of stainless-steel wires used in pull-out test, inspection certificate 3.1
$N_{Ru,\,t,\,ucr,\,st,\,i}$	N	Converted ultimate tensile force in pull-out test i, in the case of steel failure
$N_{R5\%,\,t,\,ucr}$	N	5 %-fractile at a confidence level of 90 %[5] of ultimate forces for steel failure and combined pull-out and concrete cone failure in uncracked concrete

Expression of results

Resistance to steel failure and combined pull-out and concrete cone failure of the single stainless-steel wire (in uncracked concrete), $N_{Rk,\,t,\,ucr}$ [N], shall be given in the ETA. Also the value of the $t_{fp,\,min}$ [mm] shall be given in the ETA, see Equation (2.2.3.8).

$$t_{fp,\,min} = z_{lts} + \text{tolerance}^{\,1)} \quad (2.2.3.8)$$

1) Tolerance acc. to EN 13369, Table C.1, column “Cross section dimension” underneath the column “Tightened tolerances”, in accordance with the thickness of unreinforced concrete plate

Where

$t_{fp,\,min}$	mm	Minimum thickness of facing panel

[4] For calculation of 5 %-fractile see Annex A.
[5] For calculation of 5 %-fractile see Annex A.

z_{lts} .... mm .... Thickness of unreinforced concrete plate in the last testing series with steel failure

2.2.4 Resistance to pull-out failure after tensile cycling loading of the single stainless-steel wire

Purpose of the assessment

Subject of assessment is resistance to pull-out failure after cycling tensile loading.

Assessment method

Resistance to pull-out shall be determined after tensile load cycles. The test shall be performed in uncracked concrete. Subject of testing is a single stainless-steel wire.

The stainless-steel wire shall be centrally arranged in a concrete plate 60 cm x 60 cm with minimum embedment depth. Concrete plate shall be C25/30, with the minimum thickness z (corresponding to the minimum thickness of the facing panel) considering tolerances given in the Equation (2.2.4.1). Testing on the concrete plate shall be performed with the minimum thickness minus tolerance. Concrete plate and concrete specimens are made as described in Clause 2.2.3.

$$z = t_{fp,\,min} - \text{tolerance}^{\,1)} \qquad (2.2.4.1)$$

1) Tolerance acc. to EN 13369, Table C.1, column “Cross section dimension” underneath the column “Tightened tolerances”, in accordance with the thickness of unreinforced concrete layer

Where:

z .... mm .... Thickness of unreinforced concrete plate
$t_{fp,\,min}$ .... mm .... Minimum thickness of facing panel, see Clause 2.2.3

The stainless-steel wires shall be loaded with cycling, sinusoidal tensile force. i.e. maximum force of max N = 0,6 · $N_{R5\%,\,t,\,ucr}$ and minimum force min N = 1 kN, for 22100 cycles (N_{cyc}). Test configuration shall be as per Figure 2.2.3.1. $N_{R5\%,\,t,\,ucr}$ is the 5 %-fractile at a confidence level of 90 % of ultimate forces for steel failure and combined pull-out and concrete cone failure in uncracked concrete, determined by tension tests in uncracked concrete for the concrete strength, see Clause 2.2.3.

The loading frequency shall not exceed 5 Hz. Lower limit for loading frequency is 1 Hz.

After cycling tensile loading, resistance to pull-out shall be tested as described in Clause 2.2.3, including conversion to characteristic concrete strength and tensile strength.

5 pull-out tests after cyclic tensile loading for one thickness of concrete plate shall be summarized in one test series.

Characteristic value of the resistance to pull-out failure after cycling tensile loading shall be determined as 5 %-fractile[6] at a confidence level of 90 %.

For cycling tensile loading test series, the mean ultimate pull-out forces and 5 %-fractile of ultimate pull-out forces shall be compared with the corresponding results according to Clause 2.2.3.

For $cv_{cy,\,t} \leq 15$ % see Equation (2.2.4.2) and Equation (2.2.4.3):

$$\alpha_{cy,\,t} = \min\left\{ \frac{N_{Rm,\,t,\,cy,\,t}}{N_{Rm,\,t,\,ucr}} \,;\, 1{,}0 \right\} \qquad (2.2.4.2)$$

$$\beta_{cv,\,cy,\,t} = 1 \qquad (2.2.4.3)$$

For $cv_{cy,\,t} > 15$ % see Equation (2.2.4.4) and Equation (2.2.4.5):

6 For calculation of 5 %-fractile see Annex A.

$$\beta_{cv,\,cy,\,t} = \frac{1}{1 + 0{,}03 \cdot (cv_{cy,\,t} - 15)} \tag{2.2.4.4}$$

$$\alpha_{cy,\,t} = \min\left\{\frac{N_{Rm,\,t,\,cy,\,t}}{N_{Rm,\,t,\,ucr}};\frac{N_{R5\,\%,\,t,\,cy,\,t}}{N_{R5\,\%,\,t,\,ucr}};1{,}0\right\} \tag{2.2.4.5.}$$

Where

$N_{Rm,\,t,\,cy,\,t}$ .... N ....Mean ultimate pull-out force of the cycling tensile loading test series
$N_{Rm,\,t,\,ucr}$ .... N ....Mean ultimate pull-out force of results according to Clause 2.2.3
$N_{R5\,\%,\,t,\,cy,\,t}$ .... N ....5 %-fractile of ultimate pull-out forces of the cycling tensile loading test series
$N_{R5\,\%,\,t,\,ucr}$ .... N ....5 %-fractile of ultimate pull-out forces of results according to Clause 2.2.3
$\alpha_{cy,\,t}$ .... –– ....Reduction factor for pull-out after cyclic tensile loading
$\beta_{cv,\,cy,\,t}$ .... –– ....Reduction factor for large scatter of pull-out after cyclic tensile loading
$cv_{cy,\,t}$ .... % ....Coefficient of variation of ultimate tension forces after cycling tensile loading
N_{cyc} .... –– ....Number of cycles

Note:

The above calculated reduction factors are to be used as input values for the Equation (2.2.3.7).

Expression of results

The characteristic value of the resistance to pull-out failure after tensile cycling loading of the single stainless-steel wire, $N_{R5\,\%,\,t,\,cy,\,t}$ [N], together with the number of cycles N_{cyc} [–] shall be given in the ETA.

2.2.5 Resistance of a stainless-steel point connector to concrete cone failure (due to tension loading) and effective embedment depth

Purpose of the assessment

Subject of assessment is concrete cone failure (due to tension loading) of the stainless-steel point connector comprising one stainless-steel sheet and more than one stainless-steel wire.

Assessment method

The wires – more than one – of the stainless-steel point connector constitute a group of stainless-steel wires in a given distance, see Figure 1.1.1. The characteristic value of the resistance of the group of stainless-steel wires in case of concrete cone failure depending on the embedment depth, concrete strength class, edge distance and centre spacing between the wires shall be determined. For that:

Effective embedment depth of stainless-steel wire in concrete h_{ef} shall be calculated out of 5 %-fractile at a confidence level of 90 % of ultimate pull-out forces in uncracked concrete of a single wire placed in concrete $N_{R5\%,\,t,\,ucr}$ in accordance with Equation (2.2.5.1):

$$h_{ef} = \left(\frac{N_{R5\,\%,\,t,\,ucr}}{k_1 \cdot \sqrt{f_{ck}}}\right)^{\frac{2}{3}} \tag{2.2.5.1}$$

Where

h_{ef} .... mm............Effective embedment depth of single stainless-steel wire in concrete
f_{ck} ....N/mm² ....Concrete compressive strength, C25/30
$N_{R5\,\%,\,t,\,ucr}$ .... N ....5 %-fractile of ultimate forces of results according to Clause 2.2.3, Equation (2.2.3.4)
k_1 ....(N/mm)^{0,5} ....Factor k_1 = 12,7 (N/mm)^{0,5}

Reference area of a stainless-steel wire shall be calculated by Equation (2.2.5.2) and Equation (2.2.5.3).

$$A^0_{c,N} = s_{cr,N}^2 \qquad (2.2.5.2)$$

and

$$s_{cr,N} = 3 \cdot h_{ef} \qquad (2.2.5.3)$$

Actual area of the group of stainless-steel wires shall be calculated by Equation (2.2.5.4).

$$A_{c,N} = s_{cr,N} \cdot (s_{cr,N} + s_{sspc}) \qquad (2.2.5.4)$$

Characteristic value of resistance of a stainless-steel point connector to concrete cone failure (due to tension loading) as a group of stainless-steel wires shall be calculated by Equation (2.2.5.5). $N_{Rk,t,ucr}$, see Clause 2.2.3, is actually the characteristic value of resistance of a single stainless-steel wire placed in concrete and not influenced by adjacent fasteners or edges of the concrete plate.

$$N_{Rk,c} = N_{Rk,t,ucr} \cdot \frac{A_{c,N}}{A^0_{c,N}} \qquad (2.2.5.5)$$

Where

$N_{Rk,c}$ .... N .... Characteristic value of resistance of a stainless-steel point connector to concrete cone failure (due to tension loading) as a group of stainless-steel wires

$N_{Rk,t,ucr}$ .... N .... Resistance to steel failure and combined pull-out and concrete cone failure of the single stainless-steel wire (in uncracked concrete), see Clause 2.2.3

$A^0_{c,N}$ .... mm² .... Reference area, see Figure 2.2.5.1.

$A_{c,N}$ .... mm² .... Actual area, limited by overlapping concrete cones of adjacent stainless-steel wires ($s \leq s_{cr,N}$) as well as by edges of the concrete member ($c \leq c_{cr,N}$), see Figure 2.2.5.2.

$s_{cr,N}$ .... mm .... Side length of the square of the reference area

s_{SSPc} .... mm .... Centre spacing between the outmost stainless-steel wires of a stainless-steel point connector as a group of stainless-steel wires

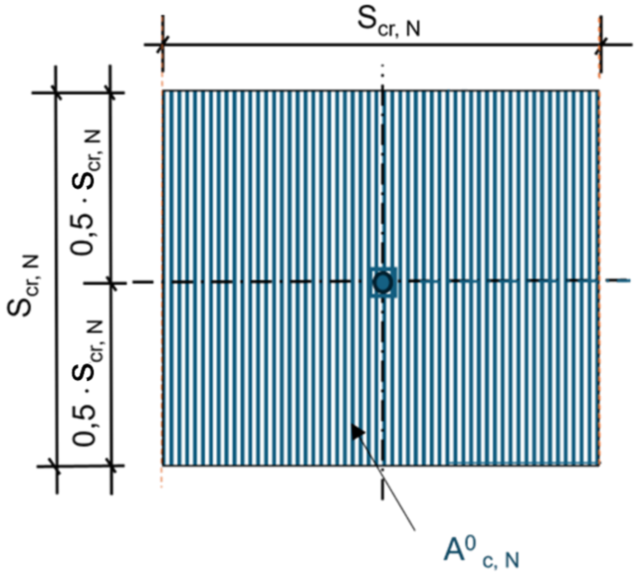


Figure 2.2.5.1: Reference area $A^0_{c,N}$ of one individual stainless-steel wire

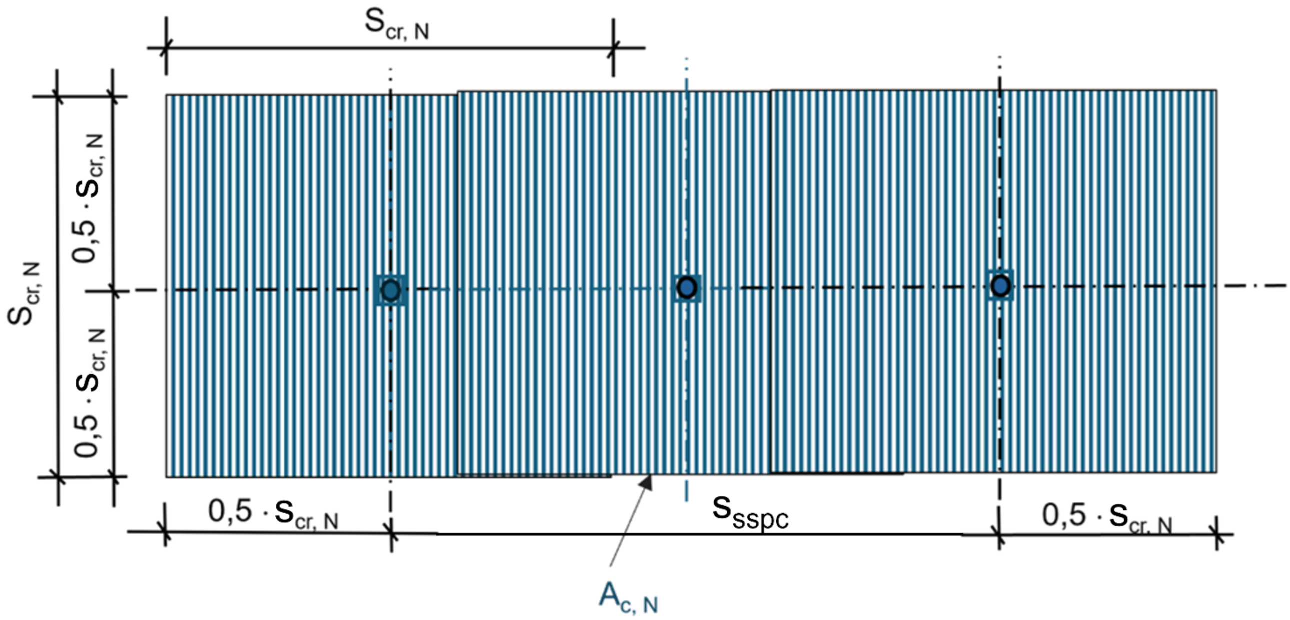


Figure 2.2.5.2: Actual area $A_{c, N}$ of the group of stainless-steel wires

Note: Figure 2.2.5.2 shows only one example of a stainless-steel point connector with 3 stainless-steel wires and overlapping areas, see Figure 1.1.1. with $s_{SSpc} = 2 \cdot s_2$

Expression of results

The characteristic value of the resistance of a stainless-steel connector to concrete cone failure (due to tension loading) $N_{Rk, c}$ [N] shall be given in the ETA. Effective embedment depth h_{ef} [mm] of the single stainless-steel wire shall be also given in the ETA.

2.2.6 Concrete splitting failure (due to tension loading) of the single stainless-steel wire and edge distance and spacing

Purpose of the assessment

Minimum values for point connector geometry (thickness of concrete layer, edge distance and spacing) shall be determined to avoid concrete splitting failure of the concrete plate due to tension loading.

Assessment method

Subject of testing shall be a single stainless-steel wire.

Concrete plate and concrete specimens are made as described in Clause 2.2.3. Thickness z is given with Equation (2.2.4.1). Test series with 3 tests with single stainless-steel wire at the corner of the concrete plate C 25/30 shall be accomplished to determine the values $c_{ucr, sp}$ and $s_{ucr, sp}$.

Starting point is the state of estimated edge distances (see Table 2.2.6.1) in both directions c_1 and c_2. If c_1 and c_2 are not given in MPII the 2nd column in Table 2.2.6.1 shall be used as starting point. These shall be either:

- gradually, steps of 10 mm, reduced to the point when concrete splitting failure occurs or
- gradually, steps of 10 mm, increased to the point when concrete splitting failure does not occur

and tested in a test series.

Edge distance without splitting, $c_{ucr, sp}$, is the smallest edge distance where splitting of the full test series does not occur.

Table 2.2.6.1: Values of c_1, c_2

In MPII	Not in MPII
$c_1 = c_2 = c_{ucr,\,sp}$	$c_1 = c_2 = 2 \cdot h_t$

Where

c_1 .... mm............edge distance in direction „1"
c_2 .... mm............edge distance in direction „2"
$c_{ucr,\,sp}$ .... mm............edge distance without splitting
h_t .... mm............embedment depth of single stainless-steel wire, in concrete considering tolerances, see Clause 2.2.3

The single stainless-steel wire shall be connected to the test rig, see Figure 2.2.6.1, and loaded to failure. The displacements of the single stainless-steel wire relative to the concrete surface shall be measured by use of either one displacement transducer on the head of the single stainless-steel wire or by use of at least two displacement transducers on either side at a distance of ≥ 1,5 · h_n from the single stainless-steel wire; the mean value of the transducer readings shall be recorded in the latter case.

When testing single stainless-steel wire at the corner of a non-cracked test member, the test rig shall be placed such that an unrestricted concrete failure towards the corner is possible (see Figure 2.2.6.1). It may be necessary to support the test rig outside the concrete layer.

The spacing is defined as $s_{ucr,sp} = 2 \cdot c_{ucr,\,sp}$.

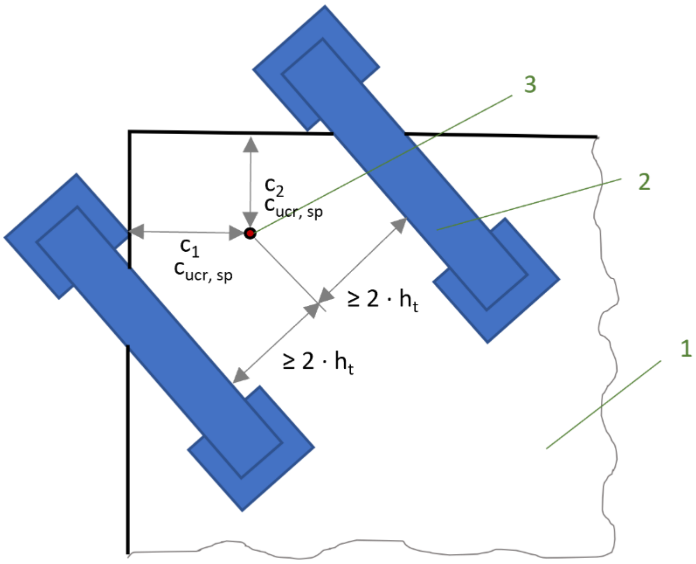


Figure 2.2.6.1: Example of the test rig for tension tests on single stainless-steel wire at a corner

Where

1 .... –..............Concrete plate, thickness z
2 .... –..............Support of test rig
3 .... –..............Single stainless-steel wire
c_1 .... mm............Edge distance in direction „1"
c_2 .... mm............Edge distance in direction „2"
h_t .... mm............Embedment depth of single stainless-steel wire, in concrete considering tolerances, see Clause 2.2.3, $h_t = z$
$c_{ucr,\,sp}$ .... mm............Edge distance without splitting
$s_{ucr,\,sp}$ .... mm............Spacing

Expression of results

Edge distance $c_{ucr,\,sp}$ [mm] and spacing $s_{ucr,\,sp}$ [mm] shall be given in the ETA.

2.2.7 Resistance to concrete pry-out failure (due to shear loading)

Purpose of the assessment

Subject of assessment is resistance to concrete pry-out failure (due to shear loading) of a whole stainless-steel point connector, as a group of stainless-steel wires.

Assessment method

Anchorages with short stiff anchors shall fail by a concrete pry-out failure at the side opposite to load direction. The corresponding characteristic resistance, $V_{Rk,cp}$, shall be calculated in accordance with Equation (2.2.7.1) with factor k_8 = 1. No supplementary reinforcement shall be considered.

$$V_{Rk,\,cp} = k_8 \cdot N_{Rk,\,c} \quad (2.2.7.1)$$

Where

$V_{Rk,\,cp}$ .... N .... Characteristic value of resistance to concrete pry-out failure (due to shear loading) of a stainless-steel point connector (as a group of stainless-steel wires)

$N_{Rk,\,c}$ .... N .... Characteristic value of resistance of a stainless-steel point connector (as a group of stainless-steel wires) to concrete cone failure (due to tension loading), see Clause 2.2.5

k_8 .... – .... Factor

Expression of results

The characteristic value of the resistance to concrete pry-out failure (due to shear loading) $V_{Rk,\,cp}$ [N] shall be given in the ETA.

2.2.8 Resistance to concrete edge failure (due to shear loading)

Purpose of the assessment

Subject of assessment is resistance to concrete edge failure (due to shear loading) of a whole stainless-steel point connector, as a group of stainless-steel wires.

Assessment method

The characteristic value of the resistance to concrete edge failure (due to shear loading) for the stainless-steel wires of the stainless-steel point connector shall be calculated in accordance with Equations (2.2.8.1) to (2.2.8.8).

$$V_{Rk,\,c} = V^0_{Rk,\,c} \cdot \frac{A_{c,\,V}}{A^0_{c,\,V}} \cdot \psi_{h,\,V} \quad (2.2.8.1)$$

and

$$V^0_{Rk,\,c} = 2{,}4 \cdot d_{nom}^{\alpha} \cdot h_{ef}^{\beta} \sqrt{f_{ck}} \cdot c_1^{1,5} \quad (2.2.8.2)$$

$$\psi_{h,\,V} = max \begin{cases} \sqrt{\dfrac{1{,}5 \cdot c_1}{z_1}} \\ 1 \end{cases} \quad (2.2.8.3)$$

$$\alpha = 0{,}1 \cdot \left(\frac{h_{ef}}{c_1}\right)^{0.5} \quad (2.2.8.4)$$

$$\beta = 0{,}1 \cdot \left(\frac{d_{nom}}{c_1}\right)^{0.2} \quad (2.2.8.5)$$

$$z_1 = t_{fp,\,min} \qquad (2.2.8.6)$$

Where

$V_{Rk,\,c}$ ..... N ..... Characteristic value of resistance of a stainless-steel point connector (as a group of stainless-steel wires) to concrete edge failure (due to shear loading)
$V^0_{Rk,\,c}$ ..... N ..... Initial value of the characteristic resistance of one stainless-steel wire that is loaded perpendicular to the edge
$A^0_{c,\,V}$ ..... mm^2 ..... Reference projected area for one stainless-steel wire, see Figure 2.2.8.1
$A_{c,\,V}$ ..... mm^2 ..... Area of the idealized concrete break out body, limited by the overlapping concrete cones of adjacent stainless-steel wires and by member thickness ($z_1 < 1{,}5 \cdot c_1$), see Figure 2.2.8.2
d_{nom} ..... mm ..... Diameter of stainless-steel wire
c_1 ..... mm ..... Edge distance in direction “1”, as given in Table 2.2.8.1
h_{ef} ..... mm ..... Effective embedment depth of single stainless-steel wire in concrete, see Clause 2.2.5
f_{ck} ..... N/mm^2 ..... Concrete compressive strength, C25/30
$\psi_{h,\,V}$ ..... – ..... Factor
z_1 ..... mm ..... Thickness of unreinforced concrete plate, see Equation (2.2.8.6), without tolerances
α, β ..... – ..... Exponent
$t_{fp,\,min}$ ..... mm ..... Minimum thickness of facing panel, see Clause 2.2.3

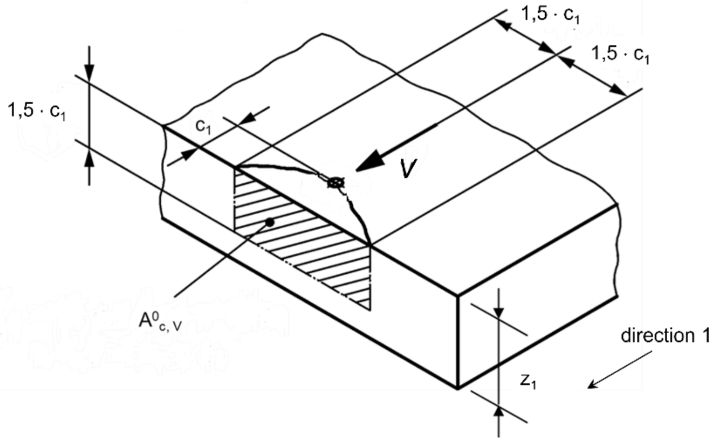


Figure 2.2.8.1: Reference projected area for one stainless-steel wire ($z_1 > 1{,}5 \cdot c_1$)

$$A^0_{c,\,V} = 4{,}5 \cdot c_1^2 \qquad (2.2.8.7)$$

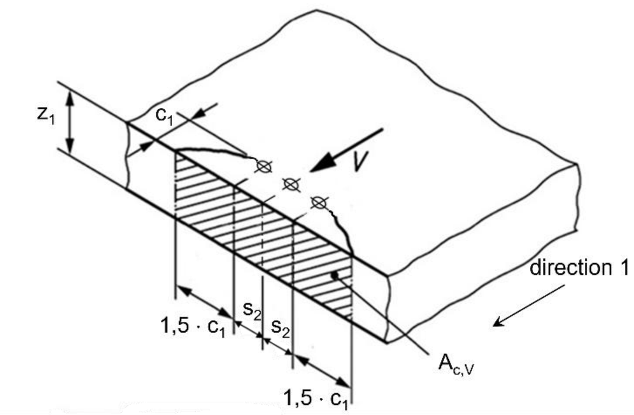


Figure 2.2.8.2: Example of the area of the idealized concrete break out body for stainless-steel point connector with three stainless-steel wires ($z_1 < 1{,}5 \cdot c_1$, $s_2 < 3 \cdot c_1$), see Figure 1.1.1

$$A_{c,V} = min \begin{cases} (3 \cdot c_1 + 2 \cdot s_2) \cdot 1{,}5 \cdot c_1 \\ (3 \cdot c_1 + 2 \cdot s_2) \cdot z_1 \end{cases} \quad (2.2.8.8)$$

Value for c_1 shall be taken as given in Table 2.2.8.1.

Table 2.2.8.1: Values of c_1

In MPII	Not in MPII
c_1	$c_1 = 2 \cdot h_{ef}$

Where

c_1 .... mm .... Edge distance in direction “1”
h_{ef} .... mm .... Effective embedment depth of single stainless-steel wire in concrete, see Clause 2.2.5
z_1 .... mm .... Thickness of unreinforced concrete plate, see Equation (2.2.8.6), without tolerances

Expression of results

The characteristic value of the resistance to concrete edge failure (due to shear loading) $V_{Rk,c}$ [N] shall be given in the ETA.

2.2.9 Minimum edge distance for the respective failure mode

Purpose of the assessment

Subject of assessment is minimum edge distance.

Assessment method

Assessment in accordance with Clause 2.2.6, Clause 2.2.7 and Clause 2.2.8 shall be carried out before the assessment according to this clause can be performed. Minimum edge distances shall be determined for each of the respective failure modes according to Table 2.2.9.1.

Table 2.2.9.1: Values of minimum edge distances for each respective failure mode

Failure mode	Minimum edge distance of the respective failure mode [mm]		Minimum centre spacing [mm]
Concrete splitting failure (due to tension loading), see Clause 2.2.6	Clause 2.2.6 regarding $c_{ucr, sp}$	$c_{ucr, sp}$	$s_{min, sp} = 2 \cdot c_{ucr, sp}$
Concrete pry-out failure, see Clause 2.2.7	Clause 2.2.8 regarding c_1 Clause 2.2.5 regarding h_{ef}	$c_{po} = \max \begin{cases} c_1 \\ 2 \cdot h_{ef} \end{cases}$	$s_{min, po} = 2 \cdot c_{po}$
Concrete edge failure (due to shear loading), see Clause 2.2.8	Clause 2.2.8 regarding c_1	$c_{ef} = c_1$	$s_{min, ef} = 2 \cdot c_{ef}$

Where

$c_{ucr, sp}$ .... mm .... Minimum edge distance from the assessment of concrete splitting failure, see Clause 2.2.6
c_{po} .... mm .... Minimum edge distance for concrete pry-out failure
c_1 .... mm .... Edge distance in direction “1”, see Clause 2.2.8
h_{ef} .... mm .... Effective embedment depth of single stainless-steel wire in concrete, see Clause 2.2.5
c_{ef} .... mm .... Minimum edge distance from the assessment of concrete edge failure
$s_{min, sp}$ .... mm .... Minimum centre spacing from the assessment of concrete splitting failure
$s_{min, po}$ .... mm .... Minimum centre spacing for concrete pry-out failure
$s_{min, ef}$ .... mm .... Minimum centre spacing from the assessment of concrete edge failure

Expression of results

Minimum edge distances of the stainless-steel point connectors for the respective failure modes at the corresponding embedment depths of the stainless-steel wires shall be given in the ETA in the format of Table 2.2.9.2.

Table 2.2.9.2: Expression of results of minimum edge distances of the stainless-steel point connectors

Failure mode	Minimum edge distance of the respective failure mode [mm]	Minimum centre spacing [mm]
Concrete splitting failure (due to tension loading)	$c_{ucr, sp}$	$s_{min, sp}$
Concrete pry-out failure	c_{po}	$s_{min, po}$
Concrete edge failure (due to shear loading)	c_{ef}	$s_{min, ef}$

2.2.10 Minimum centre spacing between stainless steel point connectors for each direction

Purpose of the assessment

Subject of assessment is minimum centre spacing between stainless steel point connectors.

Assessment method

Minimum centre spacing s_{min} between the stainless-steel point connectors of the respective failure mode shall be two times minimum edge distance for each failure mode, see Table 2.2.9.1.

Expression of results

Minimum centre spacings between the stainless-steel point connectors of the respective failure mode shall be given in the ETA, in the format of Table 2.2.9.2.

2.2.11 Resistance to shear

Purpose of the assessment

Subject of assessment is resistance to shear.

Assessment method

The reaction of the stainless-steel point connector embedded in concrete during shear loading shall be assessed by shear tests.

The dimensions of the test specimen are height H x width B = $(2 \cdot c_{min, x} + H_{con, x}) \times (2 \cdot c_{min, y} + s_{min, y})$ and maximum clearance d_{max} between base and facing panel as given in Figure 2.2.11.1. Unless specified, in the MPII the minimum edge distances and minimum centre spacings according to the respective distances in Clause 2.2.9 and Clause 2.2.10 shall be adopted for shear loading. The 2 stainless-steel point connectors shall be embedded in reinforced concrete layer with the minimum embedment depth h_{min} on both sides of the test specimen, see Figure 2.2.11.1. Minimum thickness of the reinforced concrete layer representing the facing panel and minimum thickness of the reinforced concrete layer representing the base panel shall be used for testing. Reinforcement ratio in both direction of ≤ 32 cm^2/m^2. Testing shall be performed in a test rig by loading at a constant speed of 1 mm/min until failure.

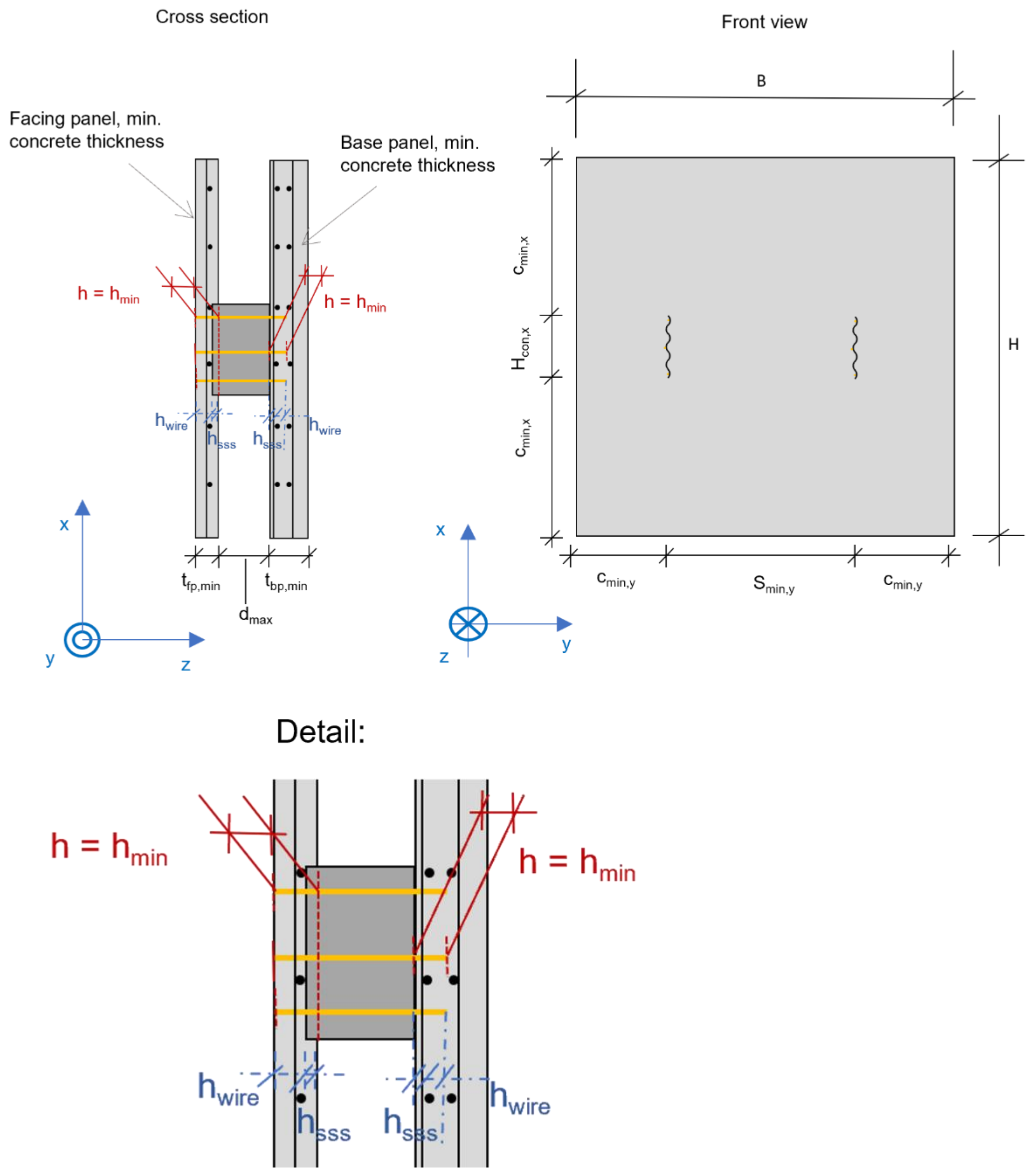


Figure 2.2.11.1: Test specimen with details – resistance to shear

The maximum clearance between base and facing panel d_{max} shall be taken from the Table 2.2.11.1:

Table 2.2.11.1: Maximum clearance between base and facing panel d_{max}

In MPII	Not in MPII
d_{max}	$d_{max} = H_{sss} - 30$ mm

Where

F..N ....Force
d_{max}................................... mm............Maximum clearance between base panel and facing panel
h .... mm............Embedment depth of stainless-steel point connector, $h = h_{wire} + h_{sss}$
h_{min} .... mm ....Minimum embedment depth of stainless-steel point connector, $h_{min} = 0,5 \cdot H_{sss} + h_{wire} - 0,5 \cdot d_{max} = h_{wire} + h_{sss}$
h_{wire}.................................. mm............Protruding length of stainless-steel wires
h_{sss} .... mm............Embedment depth of stainless-steel sheet in the concrete
H_{sss}.................................. mm............Total length of stainless-steel sheet
$t_{fp, min}$ .... mm ....Minimum thickness of facing panel
$t_{bp, mi}$................................. mm............Minimum thickness of base panel
$c_{min, x}$ .... mm............Minimum edge distance in x-direction of the stainless-steel point connector, as given in Figure 2.2.11.1 and Table 2.2.11.2

$c_{min,\,y}$ .... mm .... Minimum edge distance in y-direction of the stainless-steel point connector, as given in Figure 2.2.11.1 and Table 2.2.11.2

$s_{min,\,y}$ .... mm .... Minimum centre spacing in y-direction of the stainless-steel point connector as given in Figure 2.2.11.1 and Table 2.2.11.2

$H_{con,\,x}$ .... mm .... Height of the stainless-steel point connector in x-direction

H .... mm .... Height of the base or facing panel

B .... mm .... Width of the base or facing panel

Table 2.2.11.2: Values of $c_{min,\,x}$, $c_{min,\,y}$ and $s_{min,\,y}$

In MPII	Not in MPII
$c_{min,\,x}$	$c_{min,\,x} \geq 2 \cdot \max \begin{cases} c_{ucr,sp} \\ c_{po} \\ c_{ef} \end{cases}$
$c_{min,\,y}$	$c_{min,\,y} \geq 2 \cdot \max \begin{cases} c_{ucr,\,sp} \\ c_{po} \\ c_{ef} \end{cases}$
$s_{min,\,y}$	$s_{min,\,y} = 2 \cdot c_{min,\,y}$

Where

$c_{ucr,\,sp}$ .... mm .... Minimum edge distance from the assessment of concrete splitting failure, see Clause 2.2.9

c_{po} .... mm .... Minimum edge distance for concrete pry-out failure, see Clause 2.2.9

c_{ef} .... mm .... Minimum edge distance from the assessment of concrete edge failure, see Clause 2.2.9

The shear test, see Figure 2.2.11.2, shall be carried out with the minimal concrete thickness of facing and base panel and the maximum clearance d_{max} between base and facing panel, where $h = h_{min} = t_{fp,\,min} = h_{wire} + h_{sss}$. For stability reasons, two stainless-steel point connectors with the minimum edge distance and the minimum centre spacing in y-direction, $s_{min,\,y}$, shall be respectively used.

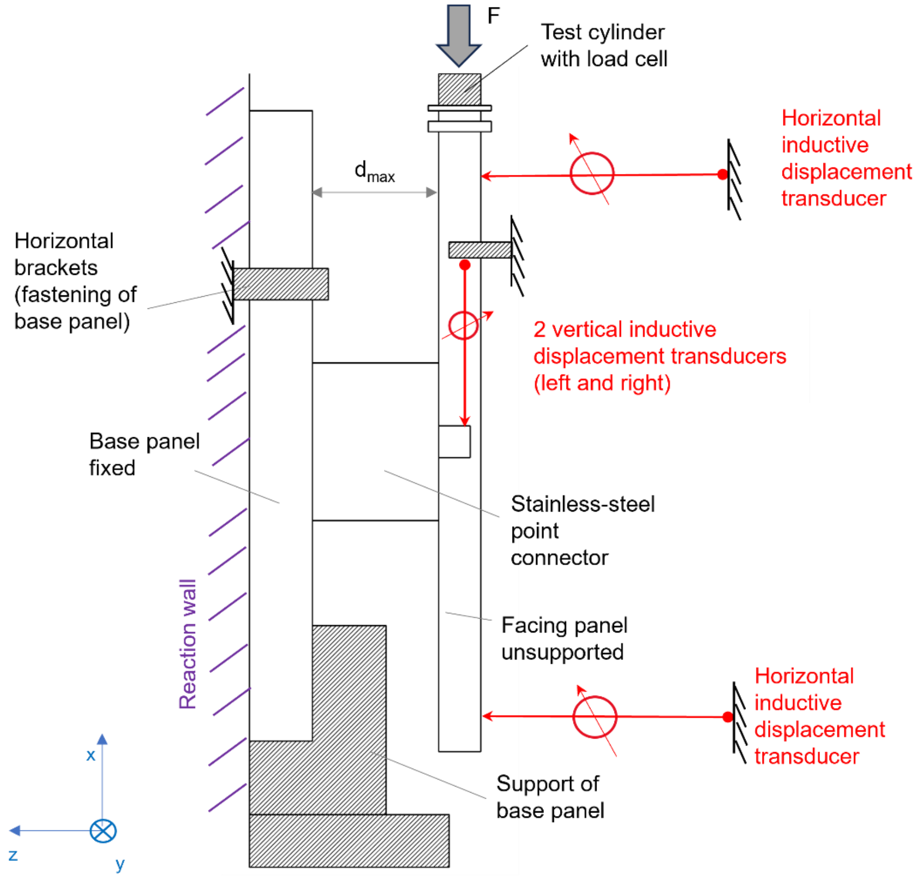


Figure 2.2.11.2: Test rig – Static shear test in x-direction

Where

F..N ....Force
d_{max}.................................. mm............Maximum clearance between base panel and facing panel

Test specimens and concrete specimens (cylinders or cubes for strength testing) shall be cured and stored indoors for seven days. 3 cylinders (diameter/height = 15 cm/ 30 cm) or 3 cubes (side length 15 cm) shall be cured for each concrete layer (base and facing panel). Thereafter they may be stored outside, provided they are protected such that frost, rain, and direct sun does not cause a deterioration of the concrete compression and tension strength. The standards EN 12390-1, EN 12390-2, and EN 12390-3 are the references for the determination of the compressive strength of the concrete for each panel at the time of testing. The concrete strength shall be determined at the time of testing. Minimum and maximum concrete strength in accordance with Clause 1.2.1.

A base panel shall be attached to the reaction wall using horizontal brackets, see Figure 2.2.11.2. A vertical support for the base panel shall prevent vertical deformations and shall absorb the resulting reaction forces. The base and facing panels shall be connected to each other by stainless-steel point connector(s) for sandwich walls. The force shall be introduced centrally into the unsupported facing panel via a test cylinder. The force applied shall be determined by a load cell integrated into the test cylinder. To determine the vertical deformations of the facing panel, two inductive displacement transducers shall be arranged at the height of the stainless-steel point connector(s) for sandwich walls. Horizontal deformations of the facing panel shall be measured using inductive displacement transducers arranged in the corners. Loading of the test specimens shall be carried out until failure. The failure mode shall be documented.

5 shear tests with test specimens corresponding to the minimum concrete strength, see Clause 1.2.1, of the panels shall be performed. If failure occurs in the concrete layers and not in the connectors, the test shall be repeated (again 5 shear tests) with test specimens corresponding to maximum concrete strength, see Clause 1.2.1. To determine the characteristic resistance to shear of one stainless-steel point connector, ultimate forces shall be evaluated statistically by determining the 5 %-fractile at a confidence level of 90 %[7].

[7] For calculation of 5 %-fractile see Annex A.

For $cv_v \leq 15$ % see Equation (2.2.11.1):

$$\beta_{cv,\,v} = 1 \qquad (2.2.11.1)$$

For $cv_v > 15$ % see Equation (2.2.11.2):

$$\beta_{cv,\,v} = \frac{1}{1 + 0{,}03 \cdot (cv_v - 15)} \qquad (2.2.11.2)$$

Characteristic value of the resistance to shear shall be calculated by Equation (2.2.11.3):

$$V_{Rk,\,v} = V_{R5\,\%,\,v} \cdot \min\left\{\frac{\alpha_{cy,\,vv}}{0{,}8} ; 1{,}0\right\} \cdot \min\left\{\beta_{cv,\,v} ; \beta_{cv,\,cy,\,vv} ; 1{,}0\right\} \qquad (2.2.11.3)$$

Where

$V_{Rk,\,v}$ .... N ....Characteristic value of the resistance to shear
$V_{R5\,\%,\,v}$ .... N ....5 %-fractile of ultimate shear forces[6]
$\alpha_{cy,\,vv}$ .... — ....Reduction factor for shear after cyclic shear loading, see Clause 2.2.14
$\beta_{cv,\,v}$ .... — ....Reduction factor for large scatter of ultimate shear forces
$\beta_{cv,\,cy,\,vv}$ .... — ....Reduction factor for large scatter of ultimate shear forces after cyclic shear loading, see Clause 2.2.14
cv_v .... % ....Coefficient of variation of ultimate shear forces

Expression of results

The characteristic value of the resistance to shear, $V_{Rk,\,v}$ [N], of the stainless-steel point connector embedded in concrete corresponding to the tested concrete strength of the panels shall be given in the ETA.

2.2.12 Stiffness in shear (displacement module)

Purpose of the assessment

Subject of assessment is stiffness in shear (displacement module).

Assessment method

Assessment in accordance with Clause 2.2.11 shall be carried out before the assessment according to this clause can be performed. Determination of stiffness in shear of the stainless-steel point connectors shall be made by shear tests and cycling shear tests. The following characteristics of the stainless-steel point connectors shall be determined:

- minimum shear stiffness in x-direction (see Clause 2.2.12.1)

- maximum shear stiffness in x-direction (see Clause 2.2.12.2)

- maximum shear stiffness in y-direction (see Clause 2.2.12.3)

Stiffness shall be determined as secant modulus and expressed by displacement module by Equation (2.2.12.1):

$$k = \frac{\Delta F}{\Delta S} \qquad (2.2.12.1)$$

Where

$$\Delta F = 40\,\% \cdot V_{RK,v} \qquad (2.2.12.2)$$

$V_{RK,v}$ .... N ....Characteristic value of the resistance to shear, see Clause 2.2.11

ΔF......................................N ....Force variation
ΔS .... mm............Displacement variation corresponding to ΔF
k .... N/mm..........Displacement module

A base panel shall be attached to the reaction wall using horizontal brackets, see Figure 2.2.11.2. A vertical support for the base panel shall prevent vertical deformations and shall absorb the resulting reaction forces. The base and facing panels shall be connected to each other by stainless-steel point connector(s) for sandwich walls. The force shall be introduced centrally into the unsupported facing panel via a test cylinder. The force applied shall be determined by a load cell integrated into the test cylinder. In order to be able to transfer compressive and tensile forces to the facing panel, the load cell shall be rigidly attached to the test cylinder and guided around the facing panel. A layer of mortar shall be placed between the load division and the facing panel in order to exclude potential misalignment of the facing panel. To determine the vertical deformations of the facing panel, two inductive displacement transducers shall be arranged at the height of the stainless-steel point connector(s) for sandwich walls. Horizontal deformations of the facing panel shall be measured using inductive displacement transducers arranged in the corners. If inclination to the vertical of the facing panel, measured with horizontal displacement transducers, within the force validation of Equation (2.2.12.2) exceeds 0,5 % (~ 0,3°), the test shall be repeated with improved guidance of test cylinder.

2.2.12.1 Minimum shear stiffness in x-direction

Minimum displacement module of the stainless-steel point connectors under the static shear stress in the x-direction is due to maximum clearance between base and facing panel d_{max} (maximum insulation thickness) and minimum concrete strength C25/30 of the panels, where stiffness in shear of the insulating material is neglected. Test specimens and concrete specimens shall be made as described in Clause 2.2.11. For static shear load simulation in the x-direction the test specimens, see Figure 2.2.12.1.1, shall be made with two stainless-steel point connectors, a minimum concrete thickness of the base panel $t_{bp,\,min}$ and of the facing panel $t_{fp,\,min}$, as well as a minimum concrete compressive strength of the panels. Reinforcement ratio of the edges in each direction of the specimen shall be ≤ 32 cm²/m².

5 static shear tests shall be performed.

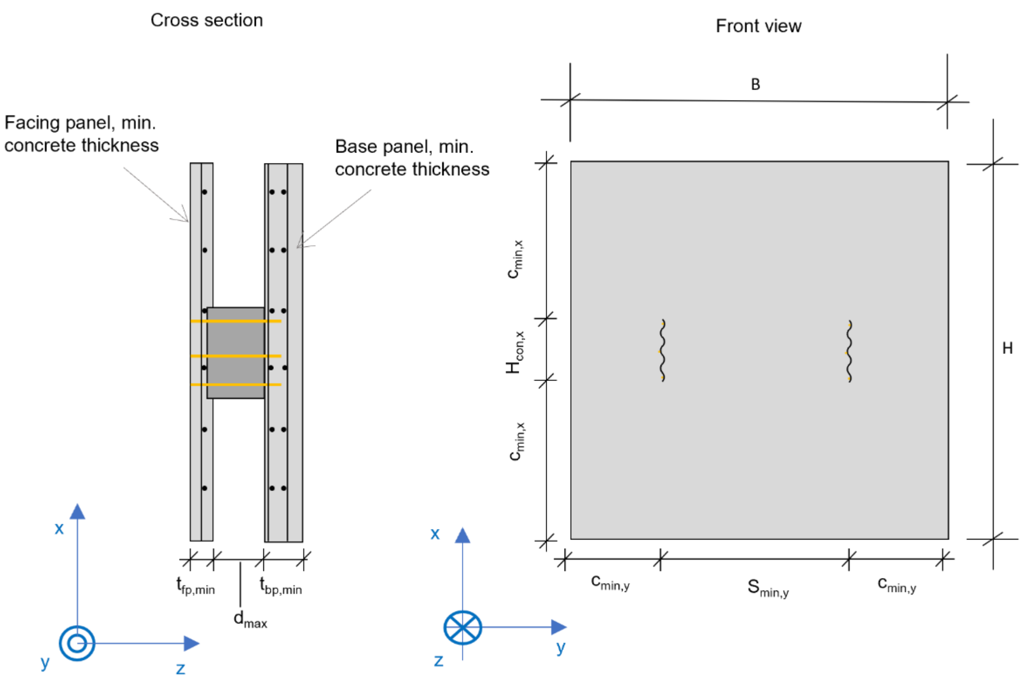


Figure 2.2.12.1.1: Test specimen for static shear test in the x-direction for determination of the minimum displacement module

Where

d_{max}.................................. mm............Maximum clearance between base panel and facing panel
$t_{fp,\,min}$ .... mm............Minimum thickness of facing panel
$t_{bp,\,min}$ .... mm............Minimum thickness of base panel, see Table 2.2.12.1

Table 2.2.12.1: Values $t_{bp,\ min}$

In MPII	Not in MPII
$t_{bp,\ min}$	$t_{bp,\ min} = \min \begin{cases} 100 \\ 2 \cdot t_{fp,\ min} \end{cases}$

Dimensions of the test specimen shall be H = 1000 mm, B = 500 mm.

2.2.12.2 Maximum shear stiffness in x-direction

Maximum displacement module of the stainless-steel point connector under static shear stress in x-direction is due to minimum clearance between base and facing panel d_{min} (minimum insulation thickness) and maximum concrete strength of the panels, where stiffness in shear of the insulating material is neglected. For static shear test in the x-direction the test specimens, shall be made with two stainless-steel point connectors, with a minimum concrete thickness of the base panel $t_{bp,\ min}$ and of the facing panel $t_{fp,\ min}$, as well as a minimum concrete compressive strength of the panels, see Figure 2.2.12.2.1. Reinforcement ratio of the edges in each direction of the specimen shall be ≤ 32 cm^2/m^2.

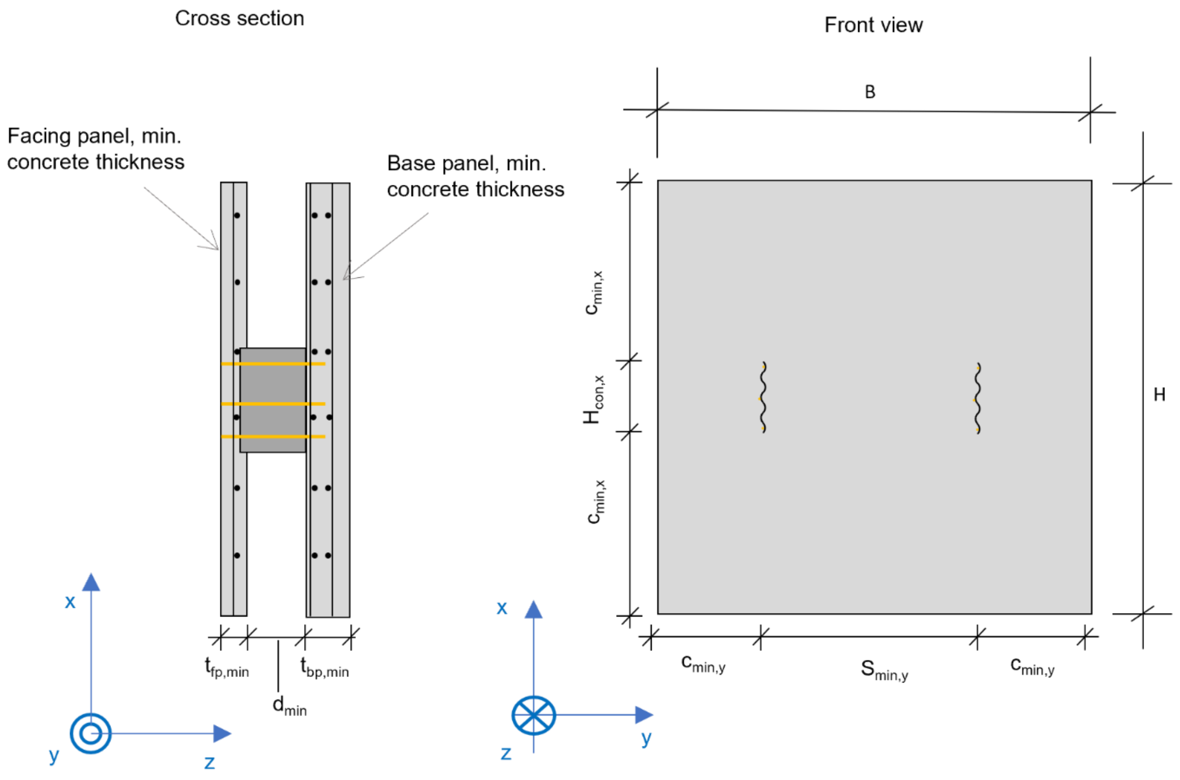


Figure 2.2.12.2.1: Test specimen for static shear test in the x-direction for determination of the maximum displacement module

Maximum displacement module of the stainless-steel point connector under cycling shear stress in x-direction is due to minimum clearance between base and facing panel d_{min} (minimum insulation thickness) and maximum concrete strength of the panels, where stiffness in shear of the insulating material is neglected.

If not specified by the manufacturer, d_{min} = 50 mm.

For the cycling shear test in x-direction the test specimens, are shown on the Figure 2.2.12.2.2, shall be made with one stainless-steel point connector, a minimum concrete thickness of the base panel and mean concrete thickness of the facing panel, as well as a maximum concrete compressive strength of the panels.

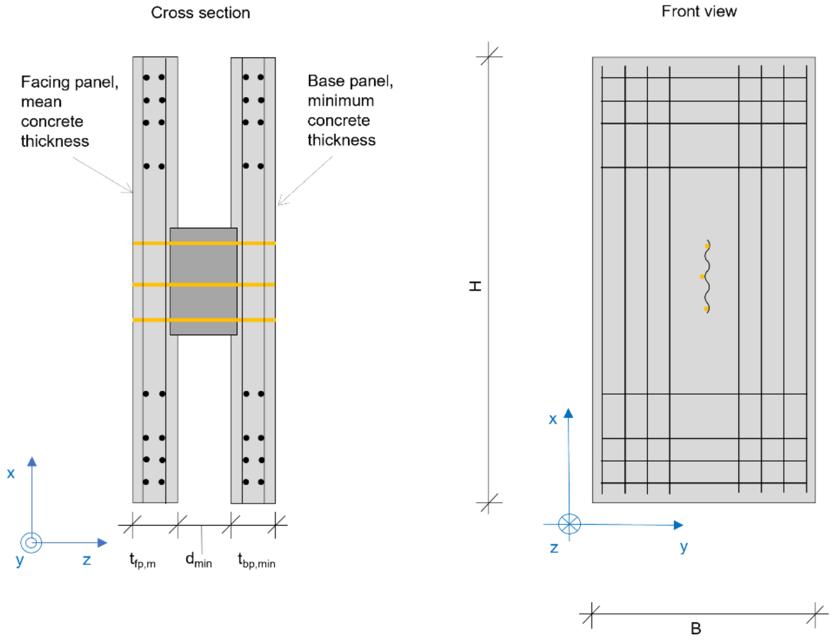


Figure 2.2.12.2.2: Test specimen for cycling shear test in x-direction for determination of the maximum displacement module

Continuously alternating mechanical load F shall be applied to the test specimens. Test rig for the cycling shear test in x-direction is shown in Figure 2.2.12.2.3.

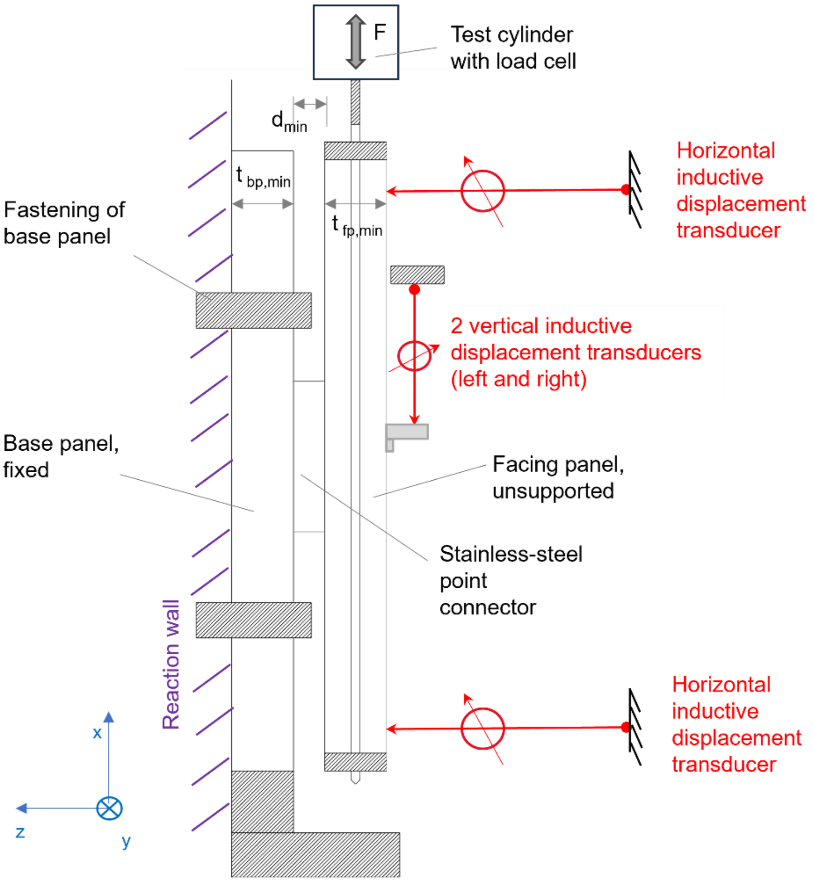


Figure 2.2.12.2.3: Test rig for the cycling shear test in x-direction for determination of the maximum displacement module

2.2.12.3 Maximum shear stiffness in y-direction

Maximum displacement module of the stainless-steel point connector under static shear stress in y-direction is due to minimum clearance between base and facing panel d_{min} (minimum insulation thickness) and maximum concrete strength of the panels, where stiffness in shear of the insulating material is neglected. Test specimens and concrete specimens shall be made as described in Clause 2.2.11.

Test rig for static shear test in y-direction is shown in Figure 2.2.12.3.1. Y-direction of the static shear force is symbolically shown on the Figure 2.2.12.3.1.

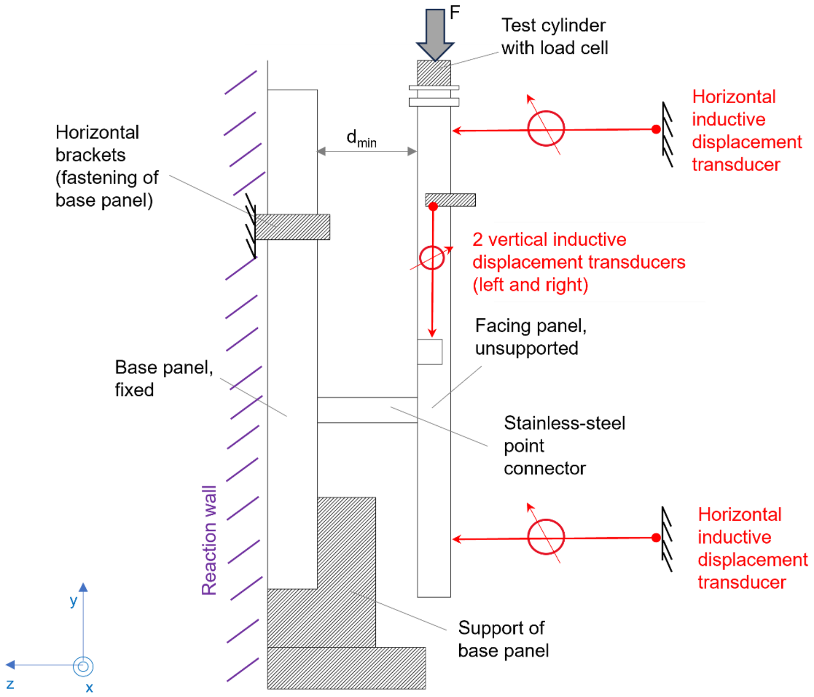


Figure 2.2.12.3.1: Test rig for static shear test in y-direction for determination of the maximum displacement module in y-direction

5 static shear tests in y-direction shall be performed.

Expression of results

2.2.12.4 Displacement module

The 5 %-fractile[8] values for the minimum displacement module at a confidence level of 75 % of the stiffness in shear in x-direction $k_{min, x}$ [N/mm] shall be given in the ETA. The 95 %-fractile[9] values for the maximum displacement module at a confidence level of 75 % of the stiffness in shear in x-direction $k_{max, x}$ [N/mm], and in y-direction $k_{max, y}$ [N/mm] shall be given in the ETA.

Where:

$k_{min, x}$ .... N/mm ....5 %-fractile values for the minimum displacement module at a confidence level of 75 % of the stiffness in shear in x-direction

$k_{max, x}$ .... N/mm ....95 %-fractile values for the maximum displacement module at a confidence level of 75 % of the stiffness in shear in x-direction

$k_{max, y}$ .... N/mm ....95 %-fractile values for the maximum displacement module at a confidence level of 75 % of the stiffness in shear in y-direction

2.2.13 Resistance to compression load (buckling and/or punching)

Purpose of the assessment

Subject of assessment is resistance to compression load (buckling and/or punching).

Assessment method

Testing of compression resistance (buckling and/or punching) means testing of the stainless-steel point connector's resistance when installed between concrete panels - base panel and facing panel - and subjected to concentric compression loads in a testing machine, see Figure 2.2.13.2.

The test specimens shall be made of stainless-steel point connectors in the width equal to minimum thermal insulation thickness and to maximum thermal insulation thickness, concreted into two reinforced concrete

[8] For calculation of 5 %- or 95%-fractile see Annex A.
[9] For calculation of 5 %- or 95%-fractile see Annex A.

panels, see Figure 2.2.13.1. Reinforcement does not influence test results. In order to enable punching through the concrete panels, mortar layers shall be placed on each outer face of the panels, see Figure 2.2.13.2.

Testing shall be performed in a test machine by loading until failure. The force shall be increased in such way that the peak force (ultimate force) occurs after 1 to 3 minutes from commencement. Testing shall be carried out on at least 6 specimens on the stainless-steel point connectors with the minimum thickness of the base panel and mean thickness of the facing panel, and with the concrete C25/30. The top panel (facing panel) shall be loaded at a constant speed until the point connector buckles/punches one concrete panel.

Expression of results

The 5 %-fractile[10] values for the resistance to compression load at a confidence level of 90 % $R_{co, 5\%fr, 90\%cl}$ [N] shall be given in the ETA.

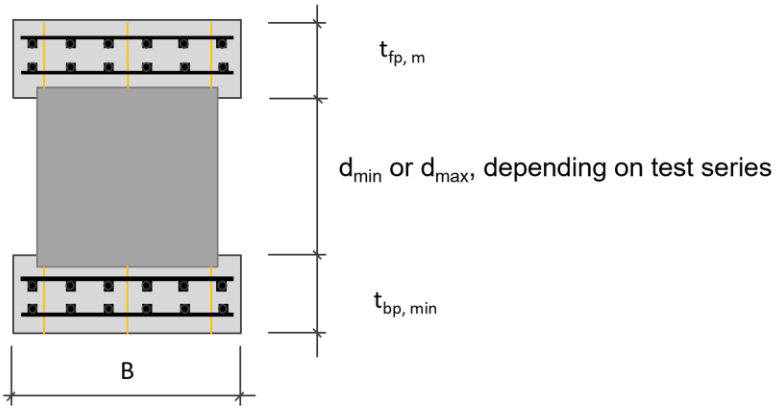


Figure 2.2.13.1: Vertical section through the test specimen

Where

B .... mm .... Width of base panel and facing panel, as width of the stainless-steel point connector + 100 mm
$t_{fp, m}$ .... mm .... Mean thickness of facing panel, see Table 2.2.13.1
$t_{bp, min}$ .... mm .... Minimum thickness of base panel, see Table 2.2.12.1
d_{min} .... mm .... Minimum clearance between base and facing panel
d_{max} .... mm .... Maximum clearance between base and facing panel
R_{co} .... N .... 5 %-fractile values for the resistance to compression load at a confidence level of 90 %

Table 2.2.13.1: Values $t_{fp, m}$

In MPII	Not in MPII
$t_{fp, m}$	$t_{fp, m} = \min \begin{cases} 100 \\ 2 \cdot t_{fp, min} \end{cases}$

[10] For calculation of 5 %- or 95%-fractile see Annex A.

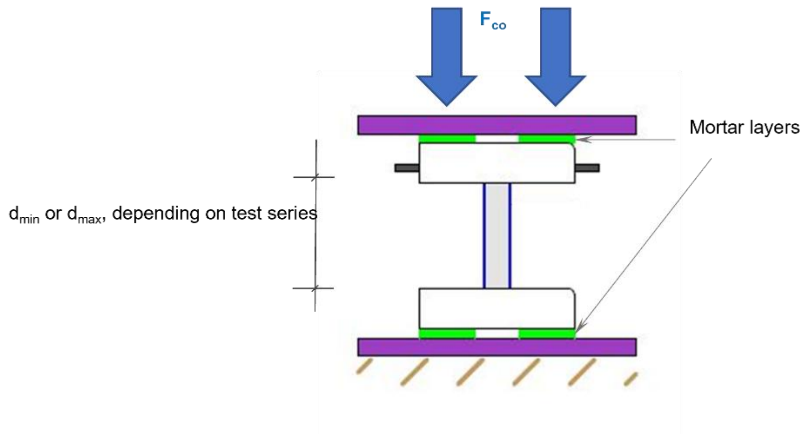


Figure 2.2.13.2: Connector embedded in concrete – Testing of buckling and punching resistance

Where

F_{co} .... N ....Compression force

2.2.14 Thermal actions – cycling shear loading

Purpose of the assessment

To assess actions caused by temperature changes on the concrete layers and therefore on the stainless-steel point connectors a continuously alternating displacement shall be applied at constant frequency to the test specimens.

Assessment method

For the cyclic load simulation, the test specimens, see Figure 2.2.14.1, shall be made with a minimum concrete thickness of base panel and mean concrete thickness of facing panel as well as a maximum concrete compressive strength. Both concrete panels shall have dimensions width B x height H. Clearance is equivalent to the lowest thickness of the thermal insulation (layer) according to MPII. An additional thickness of the thermal insulation layer shall also be tested. The base panel shall be fixed, and the facing panel shall be exposed to load cycles (unsupported).

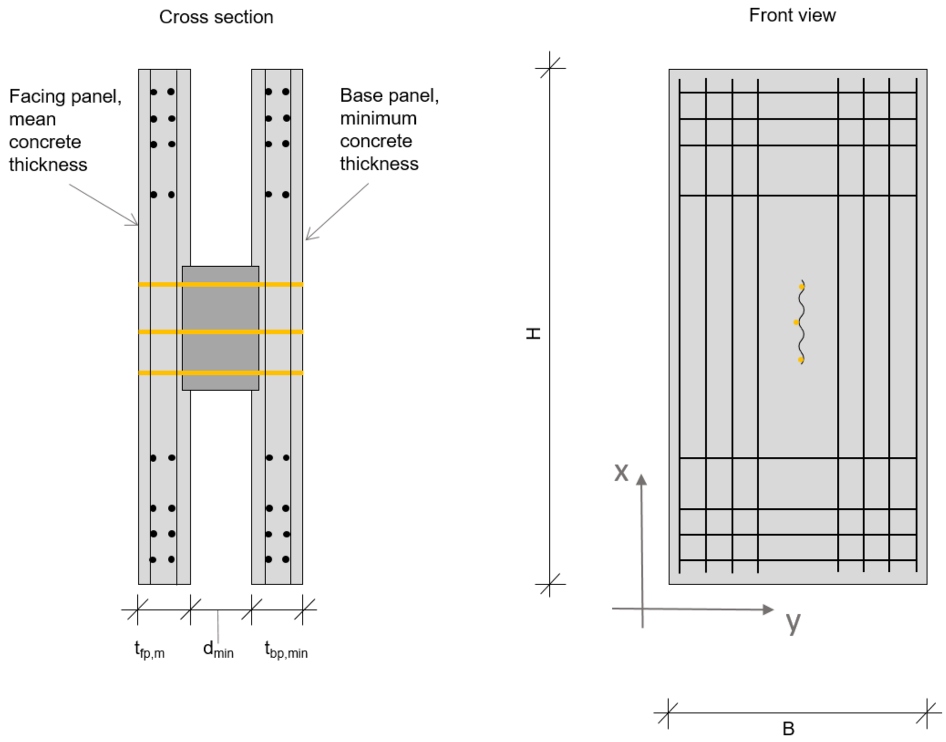


Figure 2.2.14.1: Test specimen – Cyclic shear test in x-direction

Test rig for the cycling shear test is shown in Figure 2.2.14.2.

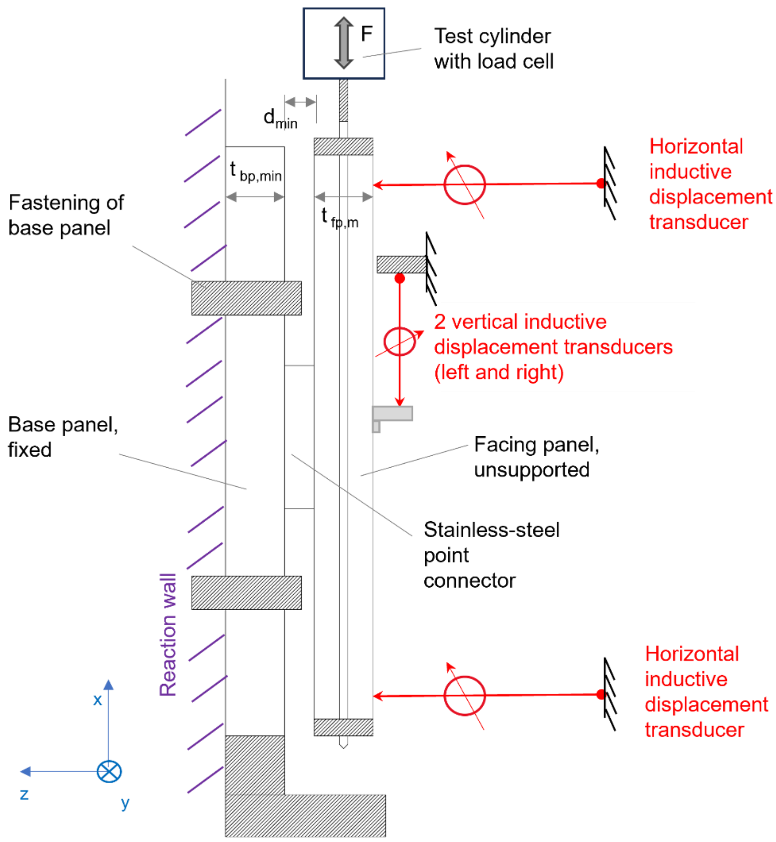


Figure 2.2.14.2: Test rig – Cyclic shear test in x-direction

Where

d_{min} .... mm...........Minimum clearance between base and facing panel
$t_{fp,m}$.................................. mm...........Mean thickness of facing panel, see Table 2.2.13.1

$t_{bp, min}$ .... mm............Minimum thickness of base panel, see Table 2.2.12.1
B....................................... mm............Width of the base or facing panel
H .... mm............Height of the base or facing panel

Test specimens and concrete specimens (cylinders or cubes for strength testing) shall be cured and stored indoors for seven days. 3 cylinders (diameter/height = 15 cm/ 30 cm) or 3 cubes (side length 15 cm) shall be cured for each concrete layer (base and facing panel). Thereafter, they shall be stored outside, provided they are protected such that frost, rain, and direct sun does not cause a deterioration of the concrete compression and tension strength. The standards EN 12390-1, EN 12390-2, and EN 12390-3 are the references for the determination of the compressive strength of the concrete for each panel. Concrete strength shall correspond to the maximum concrete strength of the panels. The concrete strength shall be determined at the time of testing.

Testing shall be carried out at embedment depth $h = t_{bp, min}$, see Figure 2.2.14.1, of the connector in base panel and minimum clearance d_{min} between base and facing panel. Further tests with greater clearance between facing and base panel shall be performed.

The minimum edge distance of the stainless-steel point connector shall be observed.

The load shall induce defined cyclic displacements of the facing panel connected to the base panel by stainless-steel point connector, see Figure 2.2.14.2. The testing machine shall be capable of repeating the displacement amplitude at the frequency ≤ 1 Hz. The testing machine shall be fitted with a counter, capable of recording the number of cycles. The accuracy of the displacement shall be within 1 % of the displacement range.

The facing panel shall be subject to cyclic displacements corresponding to the temperature spectrum of Table 2.2.14.1 and Figure 2.2.14.3. Displacement shall be induced sinusoidal with time with a frequency of ≤ 1 Hz.

For stainless-steel point connectors, which are used to install the facing panel unsupported, the displacements resulting from these temperatures shall be calculated as shown in Equation (2.2.14.1):

$$v_h = \pm \frac{c \cdot \alpha_c \cdot \Delta T}{4} \qquad (2.2.14.1)$$

For stainless-steel point connectors, which are used to install the facing panel supported, the displacements resulting from these temperatures shall be calculated as shown in Equation (2.2.14.2):

$$v_h = \pm \frac{c \cdot \alpha_c \cdot \Delta T}{2} \qquad (2.2.14.2)$$

Where

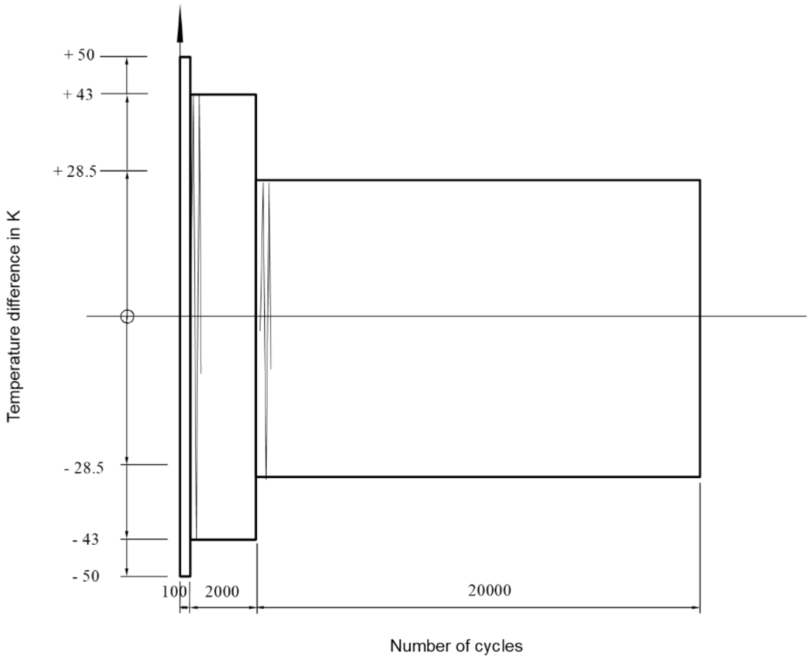
α_c....................................... K^{-1}.............Linear coefficient of thermal expansion, i.e., $\alpha_c = 10 \cdot 10^{-6}\ K^{-1}$ linear coefficient of thermal expansion for concrete
ΔT....................................... K..............Total temperature difference in K
c .... mm............Maximum height of the horizontal sandwich panel or maximal width of the vertical sandwich panel, see Table 2.2.14.2
v_h...................................... mm............Lateral displacement in mm

Table 2.2.14.1: Temperature spectrum for cyclic displacement test

Number of displacement cycles	Total temperature difference
100 displacement cycles corresponding to	$\Delta T = 100$ K
2 000 displacement cycles corresponding to	$\Delta T = 86$ K
20 000 displacement cycles corresponding to	$\Delta T = 57$ K

Table 2.2.14.2: Values of c

In MPII	Not in MPII
c	- Supported facing panel: c = 3,0 m - Unsupported facing panel: c = 6,0 m



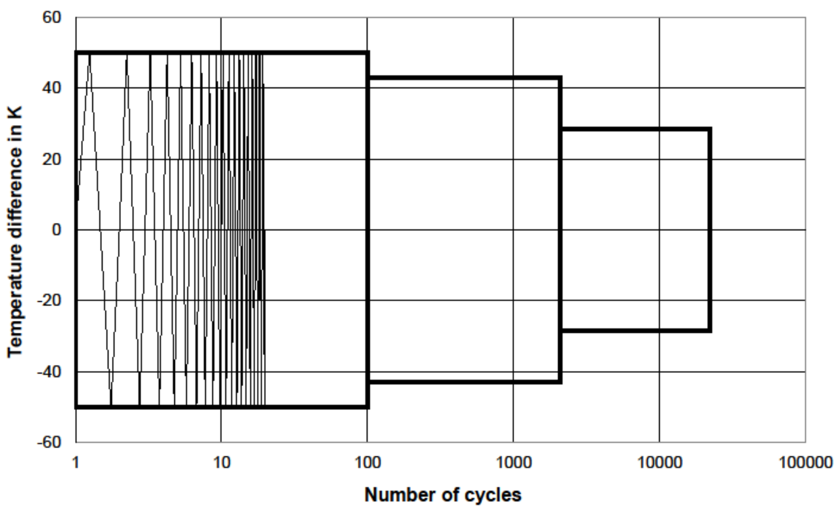


Figure 2.2.14.3: Temperature spectrum for cyclic displacement test – Schematic and in scale

After the cyclic displacement test, the stainless-steel point connector and the adjacent concrete shall be free of cracks and spalling. If such failure occurred in concrete, the test shall be repeated with dimension c according to Table 2.2.14.2 reduced by 0,5 m. At the end of cycles, a shear test according to Clause 2.2.11 and pull-out test according to Clause 2.2.3 until failure shall be performed. For the pull-out test after cycling shear loading each of the single stainless-steel wires shall be individually taken from the test specimens after the cyclic shear test is completed and tested in the pull-out test. At least 5 specimens shall be subjected to static shear test after cyclic shear loading. Number of specimens for pull-out tests shall be sufficient to perform at least 5 pull-out tests on single stainless-steel wires after cycling shear loading.

For cycling test series, the mean ultimate forces and 5 %-fractile[11] of ultimate forces at a confidence level of 90 % shall be compared with the corresponding results according to Clause 2.2.3 and Clause 2.2.11.

For pull-out after cyclic shear loading applies:

For $cv_{cy, vt} \leq 15$ % see Equation (2.2.14.3):

$$\alpha_{cy, vt} = \min \left\{ \frac{N_{Rm, t, cy, vt}}{N_{Rm, t, ucr}} \vdots 1{,}0 \right\} \quad (2.2.14.3)$$

$$\beta_{cv, cy, vt} = 1$$

For $cv_{cy, vt} > 15$ % see Equation (2.2.14.4) and Equation (2.2.14.5):

$$\beta_{cv, cy, vt} = \frac{1}{1 + 0{,}03 \cdot (cv_{cy, vt} - 15)} \quad (2.2.14.4)$$

$$\alpha_{cy, vt} = \min \left\{ \frac{N_{Rm, t, cy, vt}}{N_{Rm, t, ucr}} \vdots \frac{N_{R5\,\%, t, cy, vt}}{N_{R5\,\%, t, ucr}} \vdots 1{,}0 \right\} \quad (2.2.14.5)$$

For shear after cyclic shear loading applies:

For $cv_{cy, vv} \leq 15$ % see Equation (2.2.14.6):

$$\alpha_{cy, vv} = \min \left\{ \frac{V_{Rm, v, cy, vv}}{V_{Rm, v}} \vdots 1{,}0 \right\} \quad (2.2.14.6)$$

$$\beta_{cv, cy, vv} = 1$$

For $cv_{cy, vv} > 15$ % see Equation (2.2.14.7) and Equation (2.2.14.8):

$$\beta_{cv, cy, vv} = \frac{1}{1 + 0{,}03 \cdot (cv_{cy, vv} - 15)} \quad (2.2.14.7)$$

$$\alpha_{cy, vv} = \min \left\{ \frac{V_{Rm, v, cy, vv}}{V_{Rm, v}} \vdots \frac{V_{R5\,\%, v, cy, vv}}{V_{R5\,\%, v}} \vdots 1{,}0 \right\} \quad (2.2.14.8)$$

Note:
The above calculated reduction factors shall be used as input values for Equation (2.2.3.7). and the Equation (2.2.11.3).

Where:

$N_{Rm, t, cy, vt}$ .... N .... Mean ultimate pull-out force of the cycling shear test series
$N_{Rm, t, ucr}$ .... N .... Mean ultimate pull-out force of results according to Clause 2.2.3
$N_{R5\,\%, t, cy, vt}$ .... N .... 5 %-fractile of ultimate pull-out forces of the cycling shear test series
$N_{R5\,\%, t, ucr}$ .... N .... 5 %-fractile of ultimate pull-out forces of results according to Clause 2.2.3
$V_{Rm, v, cy, vv}$ .... N .... Mean ultimate shear force of the cycling shear test series
$V_{Rm, v}$ .... N .... Mean ultimate shear force of results according to Clause 2.2.11
$V_{R5\,\%, v, cy, vv}$ .... N .... 5 %-fractile of ultimate shear forces of the cycling shear test series
$V_{R5\,\%, v}$ .... N .... 5 %-fractile of ultimate shear forces of results according to Clause 2.2.11
$\alpha_{cy, vt}$ .... — .... Reduction factor for pull-out after cycling shear loading
$\alpha_{cy, vv}$ .... — .... Reduction factor for shear after cycling shear loading
$\beta_{cv, cy, vt}$ .... — .... Reduction factor for large scatter of pull-out forces
$\beta_{cv, cy, vv}$ .... — .... Reduction factor for large scatter of shear forces
$cv_{cy, vt}$ .... % .... Coefficient of variation of ultimate pull-out forces of the cycling shear test series

[11] For calculation of 5 %-fractile see Annex A.

$cv_{cy, vv}$ ....% ....Coefficient of variation of ultimate shear forces of the cycling shear test series

Expression of results

Dimension, c [mm], of the sandwich panel together with the values of the reduction factors $\alpha_{cy, vt}$ [–], $\alpha_{cy, vv}$ [–], $\beta_{cv, cy, vt}$ [–] and $\beta_{cv, cy, vv}$ [–] shall be given in the ETA.

3 ASSESSMENT AND VERIFICATION OF CONSTANCY OF PERFORMANCE

3.1 System of assessment and verification of constancy of performance

For the products covered by this EAD the applicable European legal act is Commission Decision 97/161/EC.

The system is 2+.

3.2 Tasks of the manufacturer

The cornerstones of the actions to be undertaken by the manufacturer of the product 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

№	Subject/type of control	Test or control method	Criteria, if any	Minimum 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	Visual inspection	check	According to Control plan	100 %	Continuously
2	Dimensions	As defined in control plan	According to Control plan	3 per test	3 per delivery
3	Material inspection	Check inspection certificate “type 3.1”	According to Control plan	100 %	Every production unit
		Steel failure due to tensile loading – tensile test of the notched and corrugated steel wires	According to Control plan	3 per test	3 per batch
4	Quality of welds	As defined in control plan	According to Control plan	100 %	Continuously

3.3 Tasks of the notified body

The cornerstones of the actions to be undertaken by the notified body in the procedure of assessment and verification of constancy of performance for the stainless-steel point connectors are laid down in Table 3.3.1.

Table 3.3.1: Control plan for the notified body; cornerstones

№	Subject/type of control	Test or control method	Criteria, if any	Minimum number of samples	Minimum frequency of control
Initial inspection of the manufacturing plant and of factory production control *(for systems 1+, 1 and 2+ only)*					
1	Notified Body will ascertain that the factory production control with the staff and equipment are suitable to ensure a continuous and orderly manufacturing of the "***stainless-steel point connectors***".	Verification of the complete FPC as described in the control plan agreed between the TAB and the manufacturer	According to Control plan	According to Control plan	When starting the production or a new line
Continuing surveillance, assessment, and evaluation of factory production control *(for systems 1+, 1 and 2+ only)*					
2	The Notified Body will ascertain that the system of factory production control and the specified manufacturing process are maintained taking account of the control plan.	Verification of the controls carried out by the manufacturer as described in the control plan agreed between the TAB and the manufacturer with reference to the raw materials, to the process and to the product as indicated in Table 3.2.1	According to Control plan	According to Control plan	once/year

4 REFERENCE DOCUMENTS

EN 10088-1:2023	Stainless steels - Part 1: List of stainless steels
EN 10088-3: 2023	Stainless steels - Part 3: Technical delivery conditions for semi-finished products, bars, rods, wire, sections and bright products of corrosion resistant steels for general purposes
EN 206: 2013+A2:2021	Concrete – Specification, performance, production and conformity
EN 12390-1:2021	Testing hardened concrete - Part 1: Shape, dimensions and other requirements for specimens and moulds
EN 12390-2:2019	Testing hardened concrete - Part 2: Making and curing specimens for strength tests
EN 12390-3:2019	Testing hardened concrete - Part 3: Compressive strength of test specimens
EN 13369: 2023	Common rules for precast concrete products
EN ISO 10456:2007+AC:2009	Building materials and products - Hygrothermal properties - Tabulated design values and procedures for determining declared and design thermal values - Technical Corrigendum (ISO 10456:2007 + Cor 1:2009)
EN ISO 6892-1:2019	Metallic materials - Tensile testing - Part 1: Method of test at room temperature (ISO 6892-1:2019)
EN 1992-4: 2018	Eurocode 2 – Design of concrete structures – Part 4: Design of fastenings for use in concrete

ANNEX A CALCULATION OF FRACTILES

Fractiles of ultimate forces or displacement moduli, measured in a test series, are calculated by Equation (A.1), Equation (A.2), Equation (A.3), and Equation (A.4).

$$5\text{ \%-fractile} = X_m \cdot \left(1 - k_n \cdot \frac{cv}{100}\right) \tag{A.1}$$

$$95\text{ \%-fractile} = X_m \cdot \left(1 + k_n \cdot \frac{cv}{100}\right) \tag{A.2}$$

$$X_m = \frac{\sum_{i=1}^{n} x_i}{n} \tag{A.3}$$

$$cv = \frac{\sqrt{\frac{1}{n-1} \cdot \sum_{i=1}^{n} (x_i - X_m)^2}}{X_m} \cdot 100 \tag{A.4}$$

For a confidence level of 90%:

n = 5 tests, k_n = 3,40

n = 10 tests, k_n = 2,57.

For a confidence level of 75%:

n = 5 tests, k_n = 2,33

n = 10 tests, k_n = 1,92

n = 15 tests, k_n = 1,84.

Where

X_m................................N or N/mm ......Mean value of ultimate forces or displacement moduli
x_i..................................N or N/mm ......Ultimate force or displacement modulus in test i
k_n....................................... —.............Factor for calculation of fractiles for n tests
n .... —.............Number of tests
cv ....% ....Coefficient of variation of ultimate forces or displacement moduli